Response to urbanisation: Aspects of the ecology of the Western Cattle Egret (*Bubulcus ibis*) with notes on population estimates in the KwaZulu-Natal Province and across South Africa

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ABSTRACT

Human population growth continues in Africa, impacting its natural fauna and flora. South Africa is experiencing a growth in population and metropolitan areas. KwaZulu-Natal is a province with the second fastest growing population in South Africa, with ~11.4 million people. This growing population is concentrated around Durban and Pietermaritzburg, the largest and second-largest cities in the province, respectively. This study focused on the city of Pietermaritzburg in the uMgungundlovu District Municipality, and Durban in the eThekwini Municipality, and their surrounding periurban areas, including communal lands and farmlands. As the response of Western Cattle Egrets (*Bubulcus ibis*) and selected heron species to urban expansion in KwaZulu-Natal Province context is poorly documented, the purpose of this study was to understand aspects of the ecology of Western Cattle Egrets in these urban mosaic landscapes.

Firstly, a literature review of the Western Cattle Egret was undertaken. Secondly, a comparison of the first Southern African Bird Atlas Project (SABAP1 conducted from 1987-1992) to the second Southern African Bird Atlas Project (SABAP2 ongoing since 2007) allowed us to observe range distribution changes of the Western Cattle Egret across South Africa. There was a significant difference for all changes observed in reporting rates between SABAP1 and SABAP2. With the exception of the Northern Cape, with a 22% decrease, provinces showed more than 60% decrease in reporting rates for the species between the two project periods. This indicated that there has been a decrease in Western Cattle Egret abundance nationally. Changes in reporting rates between SABAP1 and SABAP2 indicated a change in distribution range possibly caused by land transformation.

Thirdly, population estimates of Western Cattle Egrets in the uMgungundlovu (Pietermaritzburg) and eThekwini (Durban) Municipalities, KwaZulu-Natal, South Africa, were

conducted over a period of 18 months. These areas are both urban mosaic landscapes with some remaining natural green areas as well as managed green spaces with urban built. A population estimate of Western Cattle Egrets was conducted within these districts, and characteristics that allow for their urban persistence were identified. No significant difference in population size existed between the breeding (~230) and the post-breeding (~470) seasons. Western Cattle Egret colonies were within 10 km of a landfill, wetland, major road, river, and grassland. In addition, nesting sites were closer to a wastewater treatment facility than roosts without nests. The nests were found on 27 trees in both commercial and residential properties. *Vachellia xanthophloea* and *Jacaranda mimosifolia* were used on commercial properties. A significant difference was observed for the mean tree height. The tallest trees used for roosting were *Eucalyptus* spp. (20.23 m) and *Jacaranda mimosifolia* (19.52 m) found at Mpophomeni. Western Cattle Egrets have become cosmopolitan, undertaking various forms of migration to exploit available resources in the urban landscape mosaic. The trends showed Western Cattle Egrets roost in urban mosaic landscapes near water. In some areas, human-egret conflict was observed. Management recommendations are made for the persistence of Western Cattle Egrets in urban mosaic landscapes.

PREFACE

The data described in this thesis were collected in KwaZulu-Natal Province, Republic of South Africa from February 2018 to February 2020. Experimental work was carried out while registered at the School of Life Sciences, University of KwaZulu-Natal, Pietermaritzburg, under the supervision of Prof Colleen T. Downs and Dr Mfundo S.T. Maseko.

This thesis, submitted for the degree of Master of Science in the College of Agriculture, Engineering and Science, University of KwaZulu-Natal, School of Life Sciences, Pietermaritzburg campus, represents original work by the author and has not otherwise been submitted in any form for any degree or diploma to any University. Where use has been made of the work of others, it is duly acknowledged in the text.

[redacted].....

January 2024

I certify that the above statement is correct and as the candidate's supervisor, I have approved this thesis for submission.

[redacted]

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Prof Colleen T. Downs

Supervisor

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DECLARATION 1 - PLAGIARISM

I, Jennifer Cele, declare that

1. The research reported in this thesis, except where otherwise indicated, is my original research.

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DECLARATION 2 - PUBLICATIONS

DETAILS OF CONTRIBUTION TO PUBLICATIONS that form part and/or include research presented in this thesis.

PUBLICATION 1 (Published)

Cattle Egret (*Bubulcus ibis* Linnaeus, 1758)

JZ Cele & CT Downs

Author contributions:

JZC conceived the paper with CTD. CTD sourced funding. JZC collected and analysed data and drafted the paper. CTD contributed valuable comments to the manuscript.

PUBLICATION 2 (Not submitted)

Comparative analysis of the first and second Southern African Bird Atlas Project (SABAP) as a tool to examine distributions of an urban exploiter across South Africa

JZ Cele, MST Maseko & CT Downs

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JZC conceived the paper with MSTM and CTD. CTD sourced funding. JZC collected the data. JZC and MSTM analysed data. JZC drafted the paper. CTD and MSTM contributed valuable comments to the manuscript.

PUBLICATION 3 (Not submitted)

Population estimates of Western Cattle Egrets using nest and roost monitoring in urban landscape mosaics in KwaZulu-Natal, South Africa and with notes on select heron species

JZ Cele, MST Maseko & CT Downs

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JZC conceived the paper with MSTM and CTD. CTD sourced funding. JZC collected the data. JZC and MSTM analysed data. JZC drafted the paper. CTD and MSTM contributed valuable comments to the manuscript.

Signed:  ……

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January 2024

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"We may encounter many defeats, but we must not be defeated" Maya Angelou

CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1 Urban ecology

Urban ecology is an increasingly vital study of wildlife in urban ecosystems (McPherson et al. 2021; Shackleton et al. 2021). With landscapes changing because of human expansion, understanding the natural ecosystem's response to these changes was deemed necessary to build a sustainable future (McPherson et al. 2021). This interdisciplinary ecological science has gained traction because of the urban sprawl caused by the global population boom (Magle et al. 2012; Symes et al. 2017; Shackleton et al. 2021). It is commonly understood that urban landscapes, with their impervious surfaces, reduce and fragment available natural environments, thus generally negatively impacting biodiversity (Altwegg et al. 2014; Archibald et al. 2017; Batary et al. 2018; McPherson et al. 2021). Such disservices occur as native vegetation is displaced by anthropogenic modifications and infrastructure, such as buildings, impervious surfaces, and alien vegetation (Davoren and Shackleton 2021), thus decreasing suitable habitat and potential foraging sites. The consequences of this are then generally displacement or declines of native fauna. This poses a threat as it alters the ecosystem services humans strongly depend upon (Batary et al. 2018).

Urbanisation has been linked to a decline in species richness when compared with neighbouring rural areas (Crooks et al. 2004; Altwegg et al. 2014; Archibald et al. 2017; Symes et al. 2017; Batary et al. 2018; McPherson et al. 2021). While this is understood, the urban matrix is not completely void of wildlife as there are urban exploiters (Altwegg et al. 2014; Archibald 2017; Symes et al. 2017; Batary et al. 2018; McPherson et al. 2021). This explains why, despite the species richness of birds typically decreasing in many cities (Ibañez-Alamo et al. 2016; Archibald et al. 2017; Batary et al. 2018), overall abundance increases, often promoting biotically

homogenous populations (Crooks et al. 2004; Aronson et al. 2014; Archibald et al. 2017; Chamberlain et al. 2017; Symes et al. 2017). Slight moderations to the natural vegetation allow for suburban adapters to persist (Charutha et al. 2021). In addition, many urban landscapes are a matrix of transformed and green spaces (natural vegetation, gardens, parks, etc.) allowing a number of bird species to exploit available resources (Downs et al. 2021). However, a landscape that has been completely transformed displaces many bird species. Rather than become eradicated (urban avoiders), urban exploiters often dominate (van Rensburg et al. 2009; McPherson et al. 2021). These native birds are resilient and will find microhabitats within cities suitable to their overall survival and reproductive fitness (McKinney 2006; McKinney 2008; Ausprey and Rodewald 2011; Brambilla et al. 2018; Maseko et al. 2019; Gumede et al. 2022). The built environment also attracts urban exploiters who are alien or introduced (Crooks et al. 2004; Symes et al. 2017). For example, where rock doves (*Columba livia*) and house sparrows (*Passer domesticus*) are concerned, highly dense cities offer opportunities (McPherson et al. 2021). They are found in 80% of urban areas across the world (Aronson et al. 2014).

Urban exploiters use anthropogenic structures for nesting and foraging, with human expansion offering the added advantage of predator displacement (Altwegg et al. 2014; McPherson et al. 2021) and supplementary feeding (Crooks et al. 2004; Fuller et al. 2008; Altwegg et al. 2014; Singh and Downs 2016a,b; Thabethe and Downs 2018; McPherson et al. 2021). While some cities (e.g., Durban, South Africa) host several specialist species that have adapted to the urban landscape mosaic, most species typically are generalists (McPherson et al. 2016a,b, 2019; Singh and Downs, 2016a,b; Maseko et al. 2019; McPherson et al. 2021) keeping to natural environments or semi-built habitats such as suburbs. Humans intentionally or unintendedly offer supplementary feeding opportunities (Fuller et al. 2008; Altwegg et al. 2014). It was found that suburban residents elevate

resource provisioning by providing additional feeding opportunities to African woolly-necked storks, *Ciconia microscelis,* and this has led to an increase in their numbers and an increase in their habitat range, including in urban areas (Thabethe and Downs 2018). Supplementary resource provisioning in its many forms has little effect on overall species richness, but it does impact abundance. Many of these are generalist species (Reynolds et al. 2021). Further studies are required to observe the health of birds fed by humans since inappropriate food is often given or there is a threat of disease transmission (Fuller et al. 2008; Altwegg et al. 2014; Thabethe and Downs 2018).

Despite their ability to adapt to urban environments, cosmopolitan species have general nuisances that leave urban dwellers with negative perceptions. In a study conducted in a highly dense city in the United States of America, Belaire et al. (2015) found that residents generally disapproved of house sparrows and European starlings (*Sturnus vulgaris*) because of their unwelcomed vocalisations and faecal damage to personal property. However, this did not affect the overall perception of the ecosystem services provided by birds. Residents generally appreciated birds within their communities as they connected them with nature (Belaire et al. 2015).

Africa is the most rapidly urbanising continent (Boon et al. 2016; McPherson et al. 2021; Josiah and Downs 2022) and is predicted to see an increase in urban land cover of 590% above 2000 levels by 2030 (Hedblom and Margui 2017). Host to pertinent urban bird biodiversity, the global south remains understudied and underrepresented in the scientific literature (Hedblom and Margui 2017). The under-studied, dense informal human settlements within city boundaries host a large population that is directly dependent on natural resources (Boon et al. 2016). However, these areas are poorly managed (Boon et al. 2016) and are often void of greenspaces, losing vital ecosystem services such as nutrient cycling, disease vector control, regulation of water sources

and air-quality (Potgieter et al. 2020). Agricultural land use and urbanisation (roads, buildings and bare land) further disconnect the naturally fragmented forests, reducing the size of the patches across the landscape (Gumede et al. 2022) and interrupting important life processes. Movement between patches by avian species for resources such as foraging habitat and nesting is necessary to complete life histories (Alexander et al. 2019). Larger patches support a higher proportion of biodiversity because of the increased dispersal opportunities (Alexander et al. 2019; Maseko et al. 2019, 2020; Gumede et al. 2022).

Urbanisation not only fragments natural areas but can completely transform landscapes (Hedblom and Margui 2017; Alexander et al. 2019; Downs et al. 2021; Gumede et al. 2022; Josiah and Downs 2022). After years of bush encroachment and planting of exotic and native trees, a savanna–grassland ecosystem was converted to a woody habitat, recomposing bird fauna (Hedblom and Margui 2017). With proper management of the mosaic of urban greenspaces natural/anthropogenic (golf courses, residential gardens and eco-estates), avian species can thrive in urban environments (Boon et al. 2016; Maseko et al. 2019, 2020; Downs et al. 2021). This is evidenced in the Ethekwini municipality in the KwaZulu-Natal Province of South Africa through the Durban Metropolitan Open Space System (D'MOSS) (Boon et al. 2016). Out of the 74 672 ha of high biodiversity habitats, 9.34% is protected (Boon et al. 2016). The municipality attempts to secure ecosystem services by implementing restoration, habitat connectivity and climate change mitigation in their spatial planning (Boon et al. 2016). This favours avian species that exhibit high plasticity to changes in the environment and their diet through the use of greenspace as corridors between suitable natural habitat patches (Maseko et al. 2019, 2020; Downs et al. 2021; Josiah and Downs 2022). Species naturally adapted to mosaic habitats navigate the effects of urban fragmentation much better than species with a wide home range. They benefit from urbanisation

because of their adaptability and ecological flexibility (Downs et al. 2021). They are using the reliability of the urban environment to seek resources such as street trees for roosting/nesting, landfills for feeding and artificial water sources (Downs et al. 2021).

1.2 Wetland birds

Since the rise in anthropogenic changing land use, especially with agriculture and urbanisation, there has been a decline in wetland habitats (Parnell et al. 1988; Murray et al. 2014; Matchett and Fleskes 2017). Wetlands often require protection status to maintain the ecosystem services provided (Parnell et al. 1988; Weis et al. 2002), such as energy replenishing grounds for migratory birds (Matchett and Flesket 2017). Aesthetics are not just a reason to protect naturally occurring wetlands but are also why artificial ponds and wetlands are generally prevalent in urban green spaces (Weis et al. 2002). Over time, artificial wetlands become hosts to various waterbird species (Weis et al. 2002; Santoro et al. 2010; Fidorra et al. 2016). The size of a wetland, natural or artificial, influences the abundance and richness of water birds (Santoro et al. 2010). How the habitat is used depends on the vegetation type, connectivity, and access to food (Abdullah et al. 2017). Certain vegetation types allow for roosting and even nesting opportunities (Santoro et al. 2010; Murray et al. 2014). By promoting biodiversity within cities, those displaced by developments can recover or, at most, find refugia in the urban landscape mosaic (Weis et al. 2002; Alexander et al. 2019a,b,c). However, cities can be relatively disruptive to these species. Human disturbance can cause physiological or behavioural changes to breeding colonies of waterbirds (Nisbet 2000).

Avifauna within the Ardeidae family are wetland-associated birds varying in size. Their behavioural plasticity allows for colonisation of natural and artificial habitats (Kazantzidis et al.

2013; Rose et al. 2019). For those which prefer a semi-arid environment, wetlands are required to establish roosts and nests (Congrains et al. 2016). This requirement causes their distribution to be associated with rainfall, prompting some species of herons to be migratory or nomadic (Congrains et al. 2016).

In recent years, some studies have focused on western cattle egrets *Bubulcus ibis* and herons in urban areas (Toloa et al. 2017). They are commonly associated with wetland roosts and nesting sites in urban landscape mosaics (Toloa et al. 2017; Issa et al. 2023; Sarlin et al. 2022). Internationally, studies suggest a link likely because of the higher cost/benefit of breeding in residential areas than non-residential areas (Orians and Wittenburger 1991; Parkes 2007; Sarlin et al. 2022; Reddy et al. 2023). Nesting in urban to peri-urban wetlands compared with rural wetlands may be because of higher nest productivity (Parkes 2007; Parkes et al. 2012; Sarlin et al. 2022). While cattle egrets generally have a clutch size of 2-3 chicks, fewer will fledge because of brood reduction (Fujioka 1985; Parkes 2007). Facultative brood reduction may be less common in residential areas with the added food sources from landfills and litter (Gherbi-Salmi et al. 2021). Nest survivorship can be credited to the levels of human disturbance (Mock et al. 1987; Parnell et al. 1988; Telfair 1994), extreme weather conditions and predation (Mock et al. 1987; Parnell et al. 1988; Telfair 1994; Samraoui 2007; Mohammedi et al. 2020; Issa et al. 2023). Incubating birds generally react to major or prolonged threats, even temporarily deserting their nest (Parnell et al. 1988; Baxter 1994; Carney and Sydeman 1999). The longer they are kept away from their nest, the more exposure the nestlings or eggs have to extreme heat, cold temperatures, and predatory birds (Parkes 2007), impairing reproduction (Metallaoui et al. 2019). Human disturbance may not cause site abandonment but negatively impacts nest survivorship (Parnell et al. 1988; Baxter 1994).

Several wetland associated herons in the family Ardeidae occur in the KwaZulu-Natal Province of South Africa, which forms part of the Afrotropical region of Africa (Okes et al. 2008; Congrains et al. 2016). Species such as the black-headed heron *Ardea melanocephala,* purple heron *Ardea purpurea*, grey heron *Ardea cineria*, goliath heron *Ardea goliath*, cattle egret *Bubulcus ibis*, great egret *Egretta alba,* squacco heron *Ardeola ralloides,* and striated heron *Butorides striata* to name a few (Frederick 2002; Hockey et al. 2005). There is relatively little known about these species in the South African context. Though understudied, birds of the Ardea family were thought to be piscivorous. However, it was found for several species, such as the black-headed heron, that their diet ranges from invertebrates, molluscs and small mammals to occasionally smaller-sized birds (Hockey et al. 2005; Kopij 2006).

1.3 Western cattle egrets

Cattle egrets exist as three subspecies (Miller and Ryder 1978; Arendt and Arendt 1988; Ahmed 2011; Congrains et al. 2016). While nearly indistinguishable, each expresses a slightly different extent of breeding plumage (Ahmed 2011). Most of Asia has *Bubulcus i. coromandus*, the eastern cattle egret, which also occurs in Oceania (Miller and Ryder 1978; Arendt and Arendt 1988; Ahmed 2011; Congrains et al. 2016). In the breeding season, their plumage is thick in texture, short and expressed as a rich, widespread rust colouration covering the throat, neck and ear coverts (Ahmed 2011). *Bubulcus i. seychellarum* occurs only in the Seychelles (Miller and Ryder 1978; Arendt and Arendt 1988; Ahmed 2011; Congrains et al. 2016). *Bubulcus i. ibis*, the western cattle egret, is native to Africa, Europe, and the western parts of Asia. This is also the subspecies which successfully colonised the Americas (Miller and Ryder 1978; Arendt and Arendt 1988; Krebs et al. 1994; Bachir et al. 2008; Ahmed 2011; Congrains et al. 2016). Compared with *B. i. coromandus,*

B. i. ibis' breeding plumage is typically long and wispy. They express a buff pigmentation in
162 patches around the crown and chest (Ahmed 2011).

The western cattle egret in Africa has significantly increased its range distribution since
164 the Last Glacial Maximum 19,000– 26,000 years ago (Congrains et al. 2016). This could be because of the increase in prey availability, particularly insects, and the expansion of large
166 herbivorous grazers who often help flush out insects (Congrains et al. 2016).

It is well documented that western cattle egrets graze in terrestrial habitats (Congrains et
168 al. 2016) and typically have a close association with mega-herbivores or domestic cattle (*Bos taurus*) (Rice 1963; Browder 1973; Thompson et al. 1982; Toloa et al. 2017). This gave rise to the
170 understanding that western cattle egrets are insectivorous as feeding alongside cattle allows for decreased foraging efforts (Thompson et al. 1982). While facilitative feeding is an advantage,
172 western cattle egrets do forage in the absence of mega-herbivores. This is especially observed in the dry season. Their broad, catholic diet (Blaker 1967; Siegfried 1971a,b; Browder 1973; Kopij
174 1999) includes both small aquatic and terrestrial species such as fish and reptiles (Siegfried 1971a,b; Kopij 1999). Siegfried (1971) and Browder (1973) have even recorded them feeding on
176 small birds. Western cattle egrets have been shown to be opportunistic feeders (Siegfried 1971a; Kamler et al. 2009; Kopij 2016, 2017).

178 In urban mosaic landscapes, where western cattle egrets roost and nest, they will travel relatively great distances to find suitable feeding habitats (Toloa et al. 2017; Kopij 2017). This
180 habitat could be an open grass field (Fasola and Alieri 1992; Toloa et al. 2017) or municipal refuse landfills (Seedikkoya et al. 2007; Kuranchie et al. 2013; Toloa et al. 2017; Noreen and Sultan
182 2020). For example, Toloa et al. (2017) observed large flocks of up to 600 cattle egrets feeding in landfills. They thrive in habitats like landfills or municipal solid-waste dumps, often feeding on

184 maggots and other suitable prey (Seedikkoya et al. 2007; Kuranchie et al. 2013). Exploiting the advantages of urban streetlights in Kampala, Uganda, they feed on bush crickets drawn to the
186 artificial brightness (Toloa et al. 2017). This appears to provide western cattle egrets ample feeding near their urban roost sites. Supplementary feeding by humans may not directly concern herons
188 and cattle egrets, but anthropogenically transformed landscapes could play an indirect role, having unintendedly created supplementary feeding opportunities.

190 In a migratory state, the western cattle egret (Browder 1973) undergoes long-distance migrations in intraspecific (Arendt 1988) and interspecific flocks of other heron species (Rice
192 1956; Arendt 1988). A social bird, this species has been shown to have higher rates of reproductive success when nesting with other avian species (Arendt 1988; Toloa et al. 2017). Given their
194 behavioural plasticity, they have successfully formed colonies in new territories like North America (Congrains et al. 2016).

196 Western cattle egrets are steadily becoming cosmopolitan species, having established resident populations worldwide (Congrains et al. 2016; Toloa et al. 2017). In Kampala, Uganda,
198 although approximately 13,000 individual cattle egrets were found roosting throughout the city, only 1,500 nests were recorded for 2014 (Toloa et al. 2017). These nesting birds form less than a
200 quarter of the total population. A bimodal breeding pattern was recorded, which coincided with local rainfall patterns (Toloa et al. 2017).

202 Western cattle egrets' longevity (oldest recapture in South Africa was 23 years old) (Kopij 2016; Rose et al. 2019) and adaptive nature could also be why the expansion of the human
204 population within Africa has been an advantage to western cattle egrets (Congrains et al. 2016). Expanding throughout southern Africa (Siegfried 1971; Kopij 2008, 2016; SABAP2 2023), the
206 species has become a common breeder (Kopij 2016, 2017).

The successful expansion of avifauna into urban areas is gaining international interest (Toloa et al. 2017), so much so that western cattle egrets are featured in the book 'Where to watch birds in world cities' (Milne 2006). African cities in Madagascar, The Gambia, Uganda, Kenya, Tanzania, Senegal, and Ghana are host to large western cattle egret colonies, some with thousands of individuals. These urban populations appear to reach sexual maturity earlier than the characteristic second year (Siegfried 1971; Kopij 2017; Toloa et al. 2017). This could be implied as a reason for such a high reproductive rate in these African cities (Toloa et al. 2017). If shown to be beneficial to breeding success, nesting in urban habitats could benefit overall fitness (Wachira 2017).

The adaptability of these cosmopolitan species is also evident in their nest site selection (Toloa et al. 2017; Wachira 2017). Eucalyptus trees *Eucalyptus* spp., although exotic, are common throughout urban and peri-urban South Africa and are important nesting sites for several bird species (McPherson et al. 2016a,b; 2019; Singh and Downs 2016b). They have also been shown to be favoured by heron species (Wachira 2017). Western cattle egrets and black-headed herons will use them for nest sites and recolonise the matured shoots of cut trees years after displacement (Wachira 2017). If Ardeidae can return to sites where they have been historically displaced, then establishing urban nesting colonies can potentially restore populations lost to habitat conversion (Wachira 2017). Artificial wetlands, or those under a degree of human influence, act as refugia as they provide additional habitat and nutrient load (Fidorra et al. 2016); they remain stable through the management of water levels (wastewater treatment works and parks) even as natural wetlands dry out or the vegetation becomes overgrown (Fidorra et al. 2016). Reproductive success can also be credited to human presence. Humans are thought to deter predators, which results in a reduction

in parental absence coupled with the additional protection of breeding adult birds and unaccompanied chicks (Wachira 2017).

1.4 Motivation for the study

Human population growth continues in Africa, impacting its natural fauna and flora (Downs et al. 2021; Gumede et al. 2022; Josiah and Downs 2022). South Africa is experiencing a growth in population and metropolitan areas (Statistics South Africa 2018). KwaZulu-Natal is a province with the second fastest-growing population in South Africa, with 11.4 million people (Statistics South Africa 2018). This growing population is concentrated around Durban and Pietermaritzburg, the largest and second-largest cities in the province, respectively (Statistics South Africa 2011). This study focused on the city of Pietermaritzburg (which lies within the uMgungundlovu District Municipality) and its' surrounding peri-urban areas, including farmlands and Durban (which lies within the eThekwini Municipality) and its' surrounding peri-urban areas including farmlands.

As mentioned, urban expansion has been known to impact wildlife negatively. The response of western cattle egrets and selected heron species to urban expansion in the KwaZulu-Natal Province and South Africa as a whole is poorly documented. This study aimed to understand current distribution patterns of western cattle egrets in South Africa along with the aspects of the ecology of western cattle egrets in an urban landscape mosaic in KwaZulu-Natal Province. It is known that roosts are primarily found in wetland habitats (Congrains et al. 2016), yet population estimates are yet to be conducted in urban wetland habitats. The present study is the first, so it is novel. Consequently, the population estimates of cattle egrets were investigated across the urban mosaic landscapes. Human-avian interactions, especially conflict with western cattle egrets were also documented. Population estimates were made across urban landscape mosaics in the

Pietermaritzburg and Durban areas, along with observations of roosts. It is unknown what the habitat requirements are for western cattle egrets in KwaZulu-Natal Province to breed in residential areas.

1.5 Arrangement of thesis

The main body of this thesis is organised as manuscripts prepared for publication in peer-reviewed journal articles. The first chapter (Chapter 1) is the Introduction, which provides a literature review of the concepts covered in this study. Chapter 2 is a review of the species globally. The next two chapters (Chapters 3 and 4) are empirical, each one covering a specific objective. Each chapter is formatted according to the journal to which it is intended to be (or has been) submitted. Because of this thesis format, a certain degree of repetition was unavoidable, especially in the methods section. However, this is deemed to be of little concern as this format allows the reader to read each chapter separately without losing the overall context of the thesis. Chapter 2 investigated the global distribution and ecology of the western cattle egret. In Chapter 3, we conducted a comparative analysis of the first and second Southern African Bird Atlas Project (SABAP) as a tool to examine distributions of an urban exploiter across South Africa. Then, in Chapter 4, we investigated the population estimates of western cattle egrets in urban landscape mosaics in KwaZulu-Natal, South Africa. Chapter 5 concludes with a discussion, summary, and recommendations following the data chapters.

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CHAPTER 2

Cattle Egret (*Bubulcus ibis* Linnaeus, 1758)

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2.1 Common names

Cattle Egret, Western Cattle Egret, Eastern Cattle Egret, Buff-Backed Heron, Cow Crane, Cow Bird, Cow Heron, Elephant Bird, Tick Bird, Rhinoceros Egret, Hippopotamus Egret, Ilanda (Zulu/Xhosa), Koereiger (Dutch), Kuhreiher (German), Heron Garde-Boeuf (French), Kohager (Swedish), Depsulgabuey Or Garrapatosa Garza De Ganado, Garza De Vaquera, Garcita De Ganado, and Garcilla Garrapatera (Spanish), Busluisvoel (Afrikaans), Abu Qerdan (Arabic).

2.2 Nomenclature

Whilst debated for many years by taxonomists, Cattle Egrets *Bubulcus ibis* are widely accepted today as members of the family Ardeidae. Originally described as *Ardea ibis* (Linnaeus 1758). Erroneously classified as an *ibis* species because of similarities with the African Sacred Ibis

556 *Threskiornis aethiopicus,* then later classified as genus *Bubulcus* by Bonaparte in 1855 because of their association with cattle (Jobling 2010; Chittenden et al. 2016). Three subspecies are
558 recognised. *Bubulcus i. coromandus* occur in Asia and Oceania. *Bubulcus i. seychellarum*, are present in the Seychelles, and *Bubulcus i. ibis* are the most widely distributed, occurring in Africa,
560 southern Europe, west Asia, and America (Ahmed 2011; Congrains et al. 2016).

562 **2.3 Distribution**

Cattle Egrets are cosmopolitan birds with a wide global distribution (Fig. 2.1). This is because of
564 their successful breeding and adaptive nature (Moralez-Silva and Del Lama 2014; Congrains et al. 2016; Toloa et al. 2017). They have undergone a dramatic range expansion since the late 1800s,
566 spreading throughout Africa, into southern Europe and beyond (Louw 2005). Cattle Egrets are considered native to Africa, southern Europe (Portugal and Spain), the Asian tropics (a southward
568 range from Japan to India) and northern Australia (Arendt 1988; Moralez-Silva and Del Lama 2014). Their current range spans continents because of decades of intra and inter-continental
570 migrations (Arendt 1988). Population estimates are at 9,999,999 individuals; thus, they are a least concerned species (BirdLife International 2016).

572 As early as the late 1800s, sightings were reported in the New World, and were thought to be accidental visitors. However, a specimen in South America was formally recorded and verified
574 years later. Emmet Blake, near Buxton, East Coast, British Guiana, found this singular bird in 1937 (Crosby 1972; Telfair 1983). Not long after, specimens were collected in Surinam and Venezuela,
576 supporting the theory of migration rather than an introduction of a captive bird by explorers (Crosby 1972; Moralez-Silva and Del Lama 2014). This was further supported by sightings of
578 entire flocks, up to 105 individuals, in Surinam in 1946 (Crosby 1972). Considered migrants

passing through the region until the discovery of nesting colonies in Columbia, along with year-long sightings by 1958.

Sightings were made in Florida, USA, during the late 1940s but were not reported. In the spring of 1952, in Lake Okeechobee, Florida, a Cattle Egret was photographed and misidentified as a snowy egret, while in that same season, a specimen was caught in Wayland, Massachusetts (Crosby 1972). Distribution along North America remained coastal in their early years of invasion into the USA (Crosby 1972; Miller and Ryder 1978; Telfair 1983). By 1962, there was evidence of breeding in Missouri, the mid-west. In 1977, nesting pairs were discovered as inland as Pelican Island, Colorado (Miller and Ryder 1979; Telfair 1983).

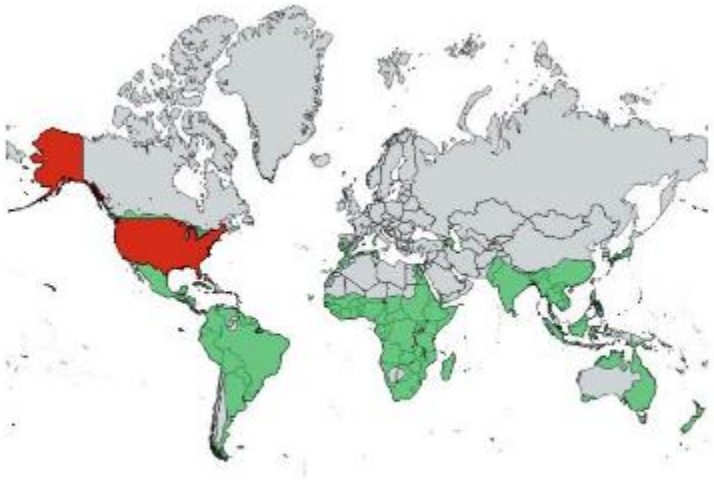

Figure 2.1: Distribution of the Cattle Egret around the world showing its natural range (green) and its invaded range (red).

2.4 Description

Cattle Egrets have little to no sexual dimorphism (Louw 2005). They are medium-sized birds (46 - 56 cm) with a wingspan of up to 88 - 96 cm and heron-like characteristics. Adults weigh 360 g on average (340- 390 g), but males can reach 512 g (Scott 1987; Telfair 2006). While most herons have long elongated necks, the Cattle Egret's is short and thick (Fig. 2.2). They have a long, sharp, yellow bill, which is orange in breeding adults. Their lore and iris are also yellow.

Cattle Egret chicks have white down feathers, a bushy crown and dark olive-green legs. A yellow bill which curves downwards. Fledglings exhibit black legs and bills, becoming yellow in juveniles. Juveniles are nearly indistinguishable from adults except over breeding periods. Sexual maturity is reached as early as 2 years of age when their legs change from a greyish-yellow to bright red during the breeding season. This is also when their typically white plumage becomes rufous around the breast, back and crown (Kaufman 1996; Telfair 2006).

Males, at times, have darker breeding plumage than females. Each subspecies experiences a slightly different extent of breeding plumage. The *B. i. coromandus*' breeding plumage is thick in texture and short and expresses a richer rust colouration covering the throat, widespread along the neck and expressed in the ear-coverts. The *B. i. ibis* has longer, wispier breeding plumage with buff pigmentation around the crown, chest, back and nape (Ahmed 2011).

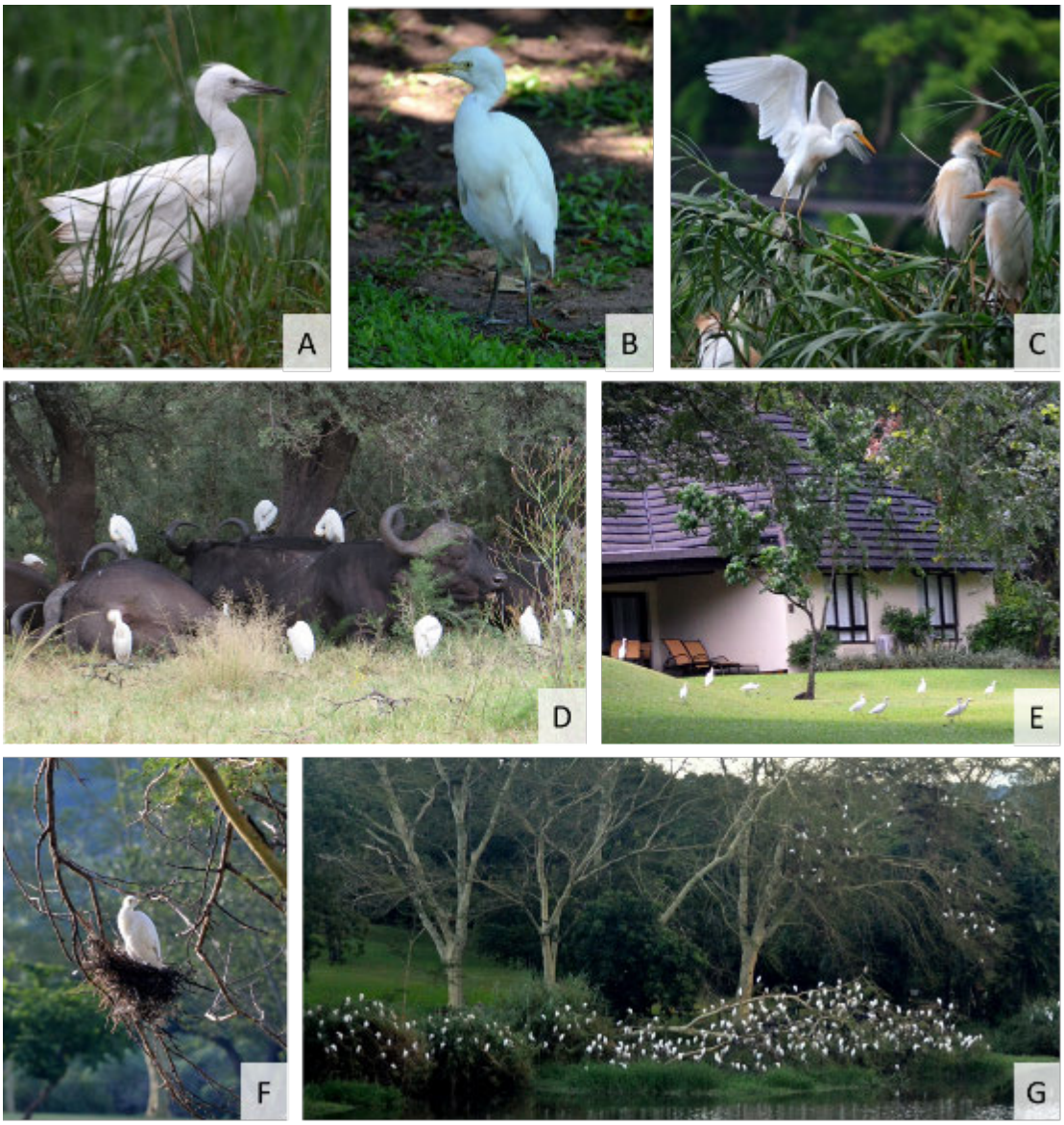

Figure 2.2: Cattle Egret images: Juvenile (A), non-breeding adult (B), breeding adults with rufous plumes (C), foraging in association with large mammals (D) and on lawns (E), stick nest (F), and large inter-species roosting flocks on reeds and fallen trees at the water's edge, with nesting birds in trees above (G). (©Photograph credits: A to C and E to G, L. Hart; photograph D, H. Jordaan). All images were taken in South Africa.

2.5 Diet

Although Cattle Egrets require proximity to a body of water for roosting and nesting, they mostly forage in terrestrial habitats (Congrains et al. 2016). They are closely associated with mega-herbivores (Rice 1963; Siegfried 1971a; 1971b; Browder 1973; Thompson et al. 1982; Kopij 1999; Telfair 2006; Toloa et al. 2017). In the presence of the African buffalo *Syncerus caffer*, cattle *Bos* spp., zebra *Equus quagga*, and even lawnmowers, their diet is mostly insectivorous, consisting of Annelida (especially earthworms). Orthoptera (grasshoppers), and Lepidoptera (caterpillars) are also important in the diet (Siegfried 1971a; 1971b; Browder 1973; Kopij 1999). Their preference for Diptera (flies) is especially important for fish farmers in India (Seedikkoya and Azeez 2009) and cattle ranchers around the world (Siegfried 1971a; 1971b; Thompson et al. 1982; Kopij 1999). This commensal strategy allows for low energy expenditure while maximising energy intake.

In the absence of mega-herbivores, Cattle Egrets are opportunistic feeders (Blaker 1967; Siegfried 1971a; 1971b; Browder 1973; Kopij 1999). Small birds, reptiles, molluscs, rodents and spiders have all been recorded as part of their diet (Siegfried 1971a; 1971b; Kopij 1999).

In urban environments, Cattle Egrets have been observed feeding on bush crickets under street lights (Toloa et al. 2017) and often fly distances from roosts to forage in municipal refuse landfills (Seedikkoya et al. 2007; Kuranchie et al. 2013; Toloa et al. 2017). They thrive in habitats like landfills or municipal solid waste dumps. These habitats become suitable since they are covered with prey ranging from maggots to insects and smaller birds (Seedikkoya et al. 2007; Kuranchie et al. 2013).

2.6 Introduction and invasion pathway

The Cattle Egret is considered an invasive species by the International Union for Conservation of Nature's Invasive Species Specialist Group (ISSG) (Moralez-Silva and Del Lama 2014). Cattle Egrets have successfully invaded many regions of the world because of their highly adaptive nature and undergoing both intra and inter-continental migrations. As migratory birds (Browder 1973), they undergo long-distance migrations in a flock of other heronry birds (Arendt 1988). Given their high adaptability, Cattle Egrets have successfully formed colonies in new territories throughout North America (Congrains et al. 2016). The Cattle Egret is an invasive alien in the Galapagos Islands (Phillips et al. 2012; Moralez-Silva and Del Lama 2014) and in Hawaii (Stone and Anderson 1988; Moralez-Silva and Del Lama 2014). They have been dispersing since the 1940s from the Malay Archipelago to New Guinea and Australia. Covering ~1600 km annually, Australia's migratory Cattle Egrets flock to New Zealand (Ahmed 2011).

Believed to have originated in eastern Africa, the Cattle Egret is now widely dispersed throughout the African continent (Arendt 1988). Ringing data reveals that Cattle Egrets can undertake a flight distance of 3750 km from their natal site. A recovery was made in the northern Central African Republic of a bird ringed in Johannesburg (Kopij 2017). This is an interesting finding since South African Cattle Egrets are thought to have migrated originally from central Africa.

It is thought that Cattle Egrets migrated from Africa to South America. Invading North America in an upward migration along the east coast, then across the Caribbean (Crosby 1972; Browder 1973). While some argue a direct migration from Africa to North America, others find this unlikely because of prevailing winds, despite a sighting aboard a trawler at sea, over 480,000 km off the coast of New Foundland, Canada (Crosby 1972). Based on meteorological projections

for an 1877 discovery in Suriname and Guyana, it is possible these early crossings originated from Senegal using tailwinds. Possible flight trajectories were simulated, proposing a 132 h direct flight from the shores of West Africa (Massa et al. 2014).

Years of ringing Cattle Egrets have enabled birders to track their movements. Australian *B. i. comorandus* have been confirmed to migrate south to New Zealand in winter. A bird tagged in the coastal town of Ballina, Australia, was recorded near Rangiriri, New Zealand, in the winter of 1990. In April 1991, a Shortland, Australia bird was recovered at Tauroa Point in Northland, New Zealand, while another, ringed in Shortland, wintered in Rangiriri. It is reported that migrants are restricted to a localised range, returning to or near the same roost yearly (Maddock and Geering 1994).

2.7 Breeding behaviour

The Cattle Egret is a highly adaptable wetland-associated species (Arendt 1988; Goutner et al. 1991; Kopij 2008). Cattle Egrets roost in mixed colonies with either terrestrial or aquatic birds (Louw 2005; Kopij 2008). It is thought that Cattle Egrets have higher rates of reproductive success when nesting in mixed colonies (Arendt 1988; Belzer and Lombardi 1989; Toloa et al. 2017). Nesting typically occurs in a tree or bush overlooking the water. Wetland habitats, such as mangroves, reed beds, thickets and marshes, are ideal for nesting colonies (Arendt 1988).

In Uttar Pradesh, India, mesquite bushes, *Prosopis juliflora,* host colonies of up to 436 Cattle Egret nests (Dwevedi et al. 2015). Unlike other findings, this site is not in proximity to water and features a monospecific colony (Dwevedi et al. 2015). In Kampala, Uganda, although approximately 13000 individual Cattle Egrets were found roosting throughout the city, only 1500 nests were recorded for 2014 (Toloa et al. 2017). These nesting birds are thought to either form

686 subpopulations or breed twice a year. A bimodal breeding pattern that coincides with local rainfall patterns was recorded. With the rainfall comes the arrival of grasshoppers and bush crickets, thus
688 creating a localised food source (Toloa et al. 2017).

When ready to attract a mate, Cattle Egret males are very vocal (Blaker, 1967; McKilligan,
690 1990). They display together whilst establishing their territories. Display behaviours include neck extensions, partially raised plumes and an open bill. In the courtship of females, males can be heard
692 giving a 'raa' call. Males display circle flights and then wingspread. If a male does not attract a female, aggression increases, and the displays become physical. Cattle Egrets have been observed
694 undertaking aerial fights and bill jabbing. Due to the male's aggression, females encroach from behind. After a few hours of courtship, a 'thonk' call is heard as pairs are formed along with back-
696 biting and bill-clappering behaviours. This can last for up to 4 days (Blaker 1967). Males who have successfully formed a pair become territorial of their nests and chosen mates for the season
698 (McKilligan 1990).

Cattle egret nests are generally untidy platforms with dry sticks, some stems of weeds
700 and/or reeds, and occasionally lined with grass (Blaker 1967; Louw 2005). Both Cattle Egret parents share responsibilities in incubating eggs as well as in feeding and guarding chicks. Eggs
702 are laid two days apart, followed by a 21 - 26 days incubation period (Blaker 1967). Clutch sizes are typically three eggs but range from 1 - 5, accounting for their relatively high breeding success
704 (Kopij 1999; Hilaluddin *et al.* 2003). If nesting fails, Cattle Egrets will reattempt nesting if the breeding season has not ended. Hatching 1 - 2 days apart, chicks become vocal and aggressive
706 with age. Lack of food resources can cause sibling aggression, with the first two hatchlings having the highest chance of survival. This is mostly experienced in their native range, which is likely the
708 reason for asynchronistic hatching. Chicks are fully feathered within 21 days, allowing them

mobility to hop in and out of their nest. By day 30, they are soon independent fledglings (Blaker 1967; Kopij 1999).

Reproductive success is higher in the New World, given the abundance of food provided by anthropogenic landscapes (Telfair 1983). Third chicks have a 98% survival rate, and fourth chicks have a 97% chance of survival to fledgling. Feeding restrictions are only limited by the parental ability to deliver food to chicks rather than the availability (Telfair 1983).

2.8 Habitat

Cattle Egret nesting and roosting sites are generally near water, but there are exceptions (Krebs et al. 1994; Parkes et al. 2012; Dwevedi et al. 2015), especially in urban areas (Louw 2005; Cele and Downs unpublished data). Foraging occurs in shallow marshes, edges of streams and rivers alongside other wading birds (Siegfried 1971a; 1971b). However, generally, wetland habitats offer limited foraging potential (Krebs et al. 1994). Therefore, they naturally occur in grassland habitats in periods of high insect abundance where they forage, obtaining a protein-rich diet in the presence of large grazers or foraging unassisted in inundated plains (Kopij 1999). Recent conversions of forests to pastureland for cattle ranching and cultivation have aided in the expansion of suitable foraging habitats (Arendt 1988; Telfair 2006; Ahmed 2011). Anthropogenic foraging habitats include urban parks, wastewater treatment facilities, organic waste refuse dumps or landfill sites, golf courses, pastures, and croplands (Louw 2005; Toloa et al. 2017; Cele and Downs unpublished data).

730 **2.9 Impacts of species**

American studies have noted competition among Cattle Egrets and native herons but not for food
732 since they differ in diet (Burger 1978; Arendt 1988). The aggressive Cattle Egret generally outcompetes for nesting space (Burger 1978; Dami et al. 2006), as observed in Camargue, France,
734 with Little Egrets *Egretta garzetta* (Dami et al. 2006). Cattle Egrets have been observed chasing young Snowy Egrets *Egretta thula* in New Jersey, USA, resulting in higher reproductive success
736 (Burger 1978). They have been observed eating chicks of native aquatic birds in Hawaii and Fernando de Noronha Archipelago, along with the endemic Noronha skink *Euprepis atlanticus*
738 (Moralez-Silva and Del Lama 2014).

In urban areas, Cattle Egrets are regarded as a nuisance species (Parkes et al. 2012).
740 Although quiet at foraging sites, they can be very noisy at roosts and messy (Cele and Downs unpublished data). Roosting trees near businesses or residences are subject to removal (Parkes et
742 al. 2012). This view is not globally shared as in some countries, they act as a biocontrol. For example, in Kampala, Uganda, there are influxes of grasshoppers coinciding with rainfall. These
744 grasshoppers often feed on cereal crops, a stable agricultural product. Additionally, grasshoppers and bush crickets would overfeed on grasses grazed by livestock without predation. Cattle Egrets,
746 which feed on grasshoppers, are welcomed by farmers who would otherwise lose revenue (Toloa et al. 2017).

748 In Indian fishing villages and organic waste refuse dump sites, Cattle Egrets can be found in large numbers feeding on maggots, including the house fly, *Musca domestica* and blue bottle
750 fly *Calliphora* spp. (Seedikkoya et al. 2007; Seedikkoya and Azeez 2009). These would otherwise pose a public health risk as they are carriers of pathogens such as cholera and typhoid once
752 metamorphosed (Seedikkoya et al. 2007). Cattle Egrets removed about 175 - 200 g maggots/day

in the fishing village on the south-west coast of India, where foraging took place for about 25 ha along Puthiyappa Beach (Seedikkoya and Azeez 2009).

2.10 Control

Cattle Egrets are often territorial and aggressive (Blaker 1967; Dusi and Dusi 1968; Burger 1978; Dami et al. 2006). They breed in large colonies, so predation efforts are made but are often unsuccessful (Blaker 1967; Dusi and Dusi 1968). In cases where predator numbers are high, entire heronries have lost young; at times, even adults are preyed upon (Dusi and Dusi 1968). Predators include snakes (eg: Gray Ratsnake in the USA), birds of prey (eg: Crowned Eagle in RSA and Barred Owl in USA) and small mammalian carnivores (Blaker 1967; Dusi and Dusi 1968). In areas where they have been introduced, roosting trees are removed to deter them, and they are sometimes trapped or shot.

2.11 Uses for this species

In the Omi-Aro and Labaka villages of Kwara State, Nigeria, the Cattle Egret is used for an annual ritual. They are taken from their nests along the riverbanks. The adult Cattle Egret is eaten as well as the eggs, leaving the feathers for use in the *Iya Efun* ceremony (Weliange et al. 2015). Nigeria is one of several countries with reported use for Cattle Egrets (Nikolaus 2001; Williams *et al.* 2014).

2.12 Notes on the species

As mentioned, Cattle Egrets have undergone both intra and inter-continental migrations. They have successfully invaded many regions of the world because of their highly adaptive nature. They

776 are gregarious creatures who migrate, roost and forage with other species and show behavioural plasticity to persist in new environments.

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2.13 References

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CHAPTER 3

Comparative analysis of the first and second Southern African Bird Atlas Project (SABAP) as a tool to examine changes in the relative abundance of an urban exploiter across South Africa

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Running header: SABAP1 and SABAP2 as a tool to examine distributions of an urban exploiter

3.1 Abstract

With Central African origins, the Western Cattle Egret (*Bubulcus ibis*) forms large roosts near wetlands. Their close human association makes them ideal for citizen science data collection. Comparing the first Southern African Bird Atlas Project (SABAP1) conducted from 1987-1992 with SABAP2 (2007-present) allowed us to observe changes in the distribution range of the Western Cattle Egret across South Africa. There was a significant difference for all changes observed in reporting rates between SABAP1 and SABAP2. Other than the Northern Cape, with a 22% decrease, provinces showed a more than 60% decrease in reporting rates for the species between the two project periods. This indicated that there has been a decrease in Western Cattle Egret abundance nationally. Changes in reporting rates between SABAP1 and SABAP2 indicated a change in relative abundance possibly caused by land transformation.

Keywords: SABAP1, SABAP2, citizen science, bird atlas project, land-use change, distribution

3.2 Introduction

Although lacking the structure of traditional scientific studies, citizen science gives researchers access to data over a geographic and temporal extent that would be costly to survey otherwise (Kery et al. 2010; Dickinson et al. 2010; Graham et al. 2015; Dennis et al. 2017). These monitoring programmes allow researchers to make inferences on the status of a population and distribution of a species (Kery et al. 2010; Hofmeyr et al. 2014; Brooks et al. 2022; Daniel and Underhill 2023). This informs management as changes over time are identified (MacKenzie and Nichols 2004; Bailey et al. 2007). Ecological research can determine where a species occurs using presence data (Graham et al. 2008; Kery et al. 2010; Dennis et al. 2017). In addition, information on how the habitat is used, as well as possible subtleties amongst metapopulations, can be assessed (Bailey et al. 2007). Citizen science data could potentially aid in determining species habitat preference and distribution data, and these could assist in a better understanding of Ardeidae habitat selection and persistence (Carrasco et al. 2014; 2017; Harebottle 2019) in an anthropogenically changing landscape.

Monitoring wildlife by non-specialists is not a new practice; however, recent developments in technology have allowed the use of new methods (Kelling et al. 2019; Brooks et al. 2022). With the advent of smartphones, wildlife monitoring has become accessible to hundreds of thousands worldwide. Volunteers with varied skill levels contribute to observations by uploading wildlife sightings on their mobile devices for many projects (Callaghan et al. 2019). This does; however, present bias as some sightings can be incorrect or go unrecorded because of skill differences or a lack of access to a site (Underhill and Brooks 2016; Dennis et al. 2017). Globally, citizen science projects are plagued by redundancies and gaps (Callaghan et al. 2019). With all the challenges associated with wildlife monitoring, citizen science is still beneficial to researchers and wildlife

managers (MacKenzie and Nickols 2004; Bailey et al. 2007; Brooks et al. 2022; Daniel and
936 Underhill 2023), to the extent that the United Nations (UN) has called on society to assist in achieving Sustainable Development Goals (SDGs) in combating the rapid loss in biodiversity. As
938 humans continue transforming the natural environment, causing a biodiversity crisis, ecologists and conservation biologists seek to understand the effects on the distribution range of species in
940 response (Marini et al. 2009; Rangel and Loyola 2012; Zhang et al. 2015).

Scientists are tasked with designing projects which motivate participation without
942 compromising scientific integrity (Daniel and Underhill 2023; Harebottle 2019). While some projects are purely opportunistic and lack structure, others have clear objectives requiring
944 scrupulously thought-out protocols (Brooks et al. 2022). Unstructured projects, however popular, do not allow for biases to be accounted for statistically, nor do they gather scientifically sound data
946 (Kelling et al. 2019). Flexible instructions attract high participation while gathering enough data to statistically account for biases and possible variation (Callaghan et al. 2019; Kelling et al. 2019).
948 Examples of citizen science bird databases include Birdlasser (Lejint (Pty) Ltd), a mobile software application which allows open participation at varied skill levels. These databases are widely used
950 to determine specific bird species' locality (Harebottle et al. 2019), distribution, and estimate their abundance (Callaghan et al. 2019; Daniel and Underhill 2023). Birdlasser even vets the
952 information uploaded, flagging anomalies (Brooks et al. 2022).

During the first South African Bird Atlas Project (SABAP1), avian species distribution
954 surveys were conducted from 1987-1992 (Martin 1997; Hofmeyr et al. 2014; Daniel and Underhill 2023). Fifteen years later, as smartphones have become more accessible, SABAP2 offers the
956 option to collect data through the Birdlasser application. This ongoing project commenced in 2007 (Daniel and Underhill 2023). Using both datasets, we compared SABAP1 with SABAP2 to

highlight changes in the Western Cattle Egret distribution across South Africa. Western Cattle Egret (*Bubulcus ibis*) populations are thought to have historically originated in Central Africa (Siegfried 1965; Kopij 2017). These gregarious colonial roosters (Carrasco et al. 2017) are easily identifiable by their size, colour, and close human association. This makes them ideal species for research (Kopij 2017), especially when data are derived from the public. The distribution of Western Cattle Egrets is predicted to be strongly influenced by land-cover variables, notably the combined presence of grasslands for foraging and wetlands for roosting. The transformation of Western Cattle Egret habitats into urban settlements is also predicted to influence the distribution of this species. The findings of this study will provide a useful tool to predict the impact of land-use change on Western Cattle Egret distribution.

3.3 Methods

3.3.1 Study area

We conducted our analyses using Western Cattle Egret SABAP data for South Africa. With a population of over 62 million (Census.StatsSA.gov.za 2022), the study area is a montage of anthropogenic and natural habitats (Thabethe and Downs 2018). Conservancies and natural greenbelts are intermingled with dense cities, suburbs and informal settlements (Symes et al. 2017; Thabethe and Downs 2018; Tricam and Shackleton 2020; McPherson et al. 2021).

3.3.2 Data extraction

Western Cattle Egret distribution data collated from the first and second SABAP projects were extracted from the Birdmap website http://sabap2.birdmap.africa/species/61. The SABAP1 study was conducted at a resolution of 15 min of latitude by 15 min of longitude in quarter degree grid

cells (QDGC), and the SABAP2 study was conducted using pentads at a resolution of 5 min latitude by 5 min longitude (Hofmyer et al. 2014; Josiah 2020). Each QDGC is equivalent to nine pentads, allowing the conversion of SABAP2 data to QDGC in 2020 for comparative analysis between the reporting rates of the two projects (Hofmyer et al. 2014). The reporting rates (RR) are the number of checklists with species report cards returned by observers divided by the total report cards placed in a QDGC (Hofmyer et al. 2014). This allows changes in geographic range to be measured from relative abundance on a species level. Underhill and Brooks (2016) presented the equation $C = \log(1 - RR2) / \log(1 - RR1)$, with C representing an estimate of relative change in species abundance between the two projects (note: $C = 1$ indicates no change in abundance, $C < 1$ shows that the abundance of reporting has decreased between the two projects and $C > 1$ indicates that abundance has increased). We present these results as a map for exploratory analysis. The data were vetted, resulting in a data set of 1878 presence localities.

3.3.3 Data analyses

Using the open-source Quantum Geographic Information System (QGIS LTR 3.28.12-Firenze) software, a geographic range map was created at a resolution of 1:50000 using quarter-degree grid cells (15' by 15'). Applying the geometry-shaded region method described in Josiah (2020), we allocated cells bordering two provinces or countries to a single province to prevent erroneously drawn conclusions because of the presence of duplications. In line with the methods described in Hofmeyr et al. (2014), cells with less than four (<4) checklists in either of the SABAP projects were excluded from statistical analysis. To facilitate spatial interpretation, we used a 7-colour system to code each classification representative of the changes in reporting rate: 'decrease', 'increase', 'never', 'new', 'absence', 'stable' and 'invalid'. Cells were further categorised as

indicating a ‘Change’ or ‘No Change’. If a value was stable between the sampling periods, then there was ‘No Change’. If there was a decrease, increase or a sighting occurred in one project but not in another (new/absent) then there was a ‘Change’ in the reporting rate. Chi-square tests at an alpha level of 0.05 were conducted on the reporting rates between the two projects according to province using IBM SPSS© Statistics version 29.0.1.0 (SPSS Inc., Chicago, USA). Invalid cells were omitted from statistical analysis but retained in the tabulation of the outcomes by province.

3.4 Results

The interest of this study was South Africa, of which 1878 presence localities were included for the study species at the time of download (08 November 2023). Within these records, 14.6% showed an increase in reporting rate (C > 1), reflecting areas with an increase in abundance. Recordings made in SABAP2 that were not recorded in SABAP1 represented 4.6% (n = 87) of the dataset. It was observed that 18.9% (n = 355) of the valid South African records had cells which never recorded Western Cattle Egret observations in either study. Only 0.4% of cells displayed no change in C-value (C = 1), while 60.4% of the QDGC records showed a decrease in C-value (C < 1). Western Cattle Egrets were completely absent from 8.6% (n = 161) of the cells, while 5.6% (n = 106) were invalid because of the low number of checklists (<4) in the cell.

There was a significant difference for all changes observed in reporting rates between SABAP1 and SABAP2 ($p < 0.05$). In South Africa as a whole, there was a significant difference in the number of QDGCs (n = 275), which reflected an overall increase in reports from SABAP1 to SABAP2 compared with QDGCs (n = 1135) that showed an overall decrease in reporting from SABAP1 to SABAP2 ($\chi^2 = 524.539$; df = 1; $p < 0.001$).

Other than the Northern Cape Province, with a 22.0% decrease, provinces showed more than a 60% in decreased reporting rates for the Western Cattle Egret between the projects (Tables 3.1 and 3.2, Fig. 3.1). Gauteng Province had the highest decrease in reporting rates at 91.3%, Mpumalanga at 87.9%, and KwaZulu-Natal Province had the third highest with an 87.9% decrease in reporting rates (Table 3.1, Fig. 3.1). The proportion of QDGCs showing a change in reporting rates between the two study periods had a significant difference. The Gauteng Province (n = 23, Fig. 3.1) had a significant difference between the number of cells reflecting an increase (n = 2) and cells reflecting a decrease in the study species (n = 21) (χ^2 = 15.696; df = 1; $p < 0.001$; Tables 3.1 and 3.2). Mpumalanga Province (n = 124, Fig. 3.1) had a significant difference between the number of cells reflecting an increase (n = 14) and cells reflecting a decrease in the study species (n = 109) (χ^2 = 73.374; df = 1; $p < 0.001$; Tables 3.1 and 3.2). KwaZulu-Natal Province (n = 165, Fig. 3.1) had a significant difference between the number of cells reflecting an increase (n = 19) and cells reflecting a decrease in the study species (n = 145) (χ^2 = 96.805; df = 1; $p < 0.001$; Tables 3.1 and 3.2). The Free State Province (n = 200, Fig. 3.1) had a significant difference between the number of cells reflecting an increase (n = 36) and cells reflecting a decrease in the study species (n = 163) (χ^2 =81.05; df = 1; $p< 0.001$; Tables 3.1 and 3.2). The Western Cape Province (n = 231, Fig. 3.1) had a significant difference between the number of cells reflecting an increase (n = 26) and cells reflecting a decrease in the study species (n = 168) (χ^2 = 103.938; df = 1; $p < 0.001$; Tables 3.1 and 3.2). The Eastern Cape Province (n = 278, Fig. 3.1) had a significant difference between the number of cells reflecting an increase (n = 47) and cells reflecting a decrease in the study species (n = 198) (χ^2 = 93.065; df = 1; $p < 0.001$; Table 3.1). Limpopo Province (n = 171, Fig. 3.1) had a significant difference between the number of cells reflecting an

increase (n = 46) and cells reflecting a decrease in the study species (n = 117) (χ^2 =30.926; df = 1; p < 0.001; Tables 3.1 and 3.2), North West Province (n = 145, Fig. 3.1) had a significant difference between the number of cells reflecting an increase (n = 22) and cells reflecting a decrease in the study species (n = 95) (χ^2 = 45.547; df = 1; p < 0.001; Tables 3.1 and 3.2). The Northern Cape Province (n = 541, Fig. 3.1) had a significant difference between the number of cells reflecting an increase (n = 63) and cells reflecting a decrease in the study species (n = 119) (χ^2 =17.231; df = 1; p < 0.001; Tables 3.1 and 3.2). Contributing to the overall decrease in reporting rates, the provinces with the largest proportion of QDGCs in which Western Cattle Egrets were recorded for SABAP1 but had not been seen in SABAP2 were Northern Cape (n = 73), Eastern Cape (n = 41) and Western Cape (n = 22). The Northern Cape also had the highest number of new recordings for the species in SABAP2, with a reporting rate of 45.

Table 3.1: Summary of Western Cattle Egret reporting rate changes in quarter degree grid cells (QDGC) for South Africa at the national and provincial levels based on SABAP 1 and 2 (As of November 2023), and the percentage of cells with no change or change.

Region	**Number of QDGCs with WCE records**	**No change (%)**	**Change (%)**		**Other* (%)**	**No change vs change**
National Level	n	Stable	Increase	Decrease		p-value
South Africa	1878	0.4	14.6	60.4	24.6	< 0.001
Provincial level						
KwaZulu-Natal	165	0	11.5	87.9	0.6	< 0.001
Eastern Cape	278	0.4	16.9	71.2	11.5	< 0.001
Gauteng	23	0	8.7	91.3	0	< 0.001
Mpumalanga	124	0	11.3	87.9	0.8	< 0.001
Free State	200	0.5	18.0	81.5	0	< 0.001
Western Cape	231	0.4	11.3	72.7	15.6	< 0.001
Northern Cape	541	0.2	11.7	22.0	66.2	< 0.001
Limpopo	171	0.6	26.9	68.4	4.1	< 0.001
North West	145	1.4	15.2	65.5	17.9	< 0.001

* QDGCs with surveyed cells with no sightings of Western Cattle Egret in SAPAB1 and SABAP2 and surveyed cells with invalid data combined.

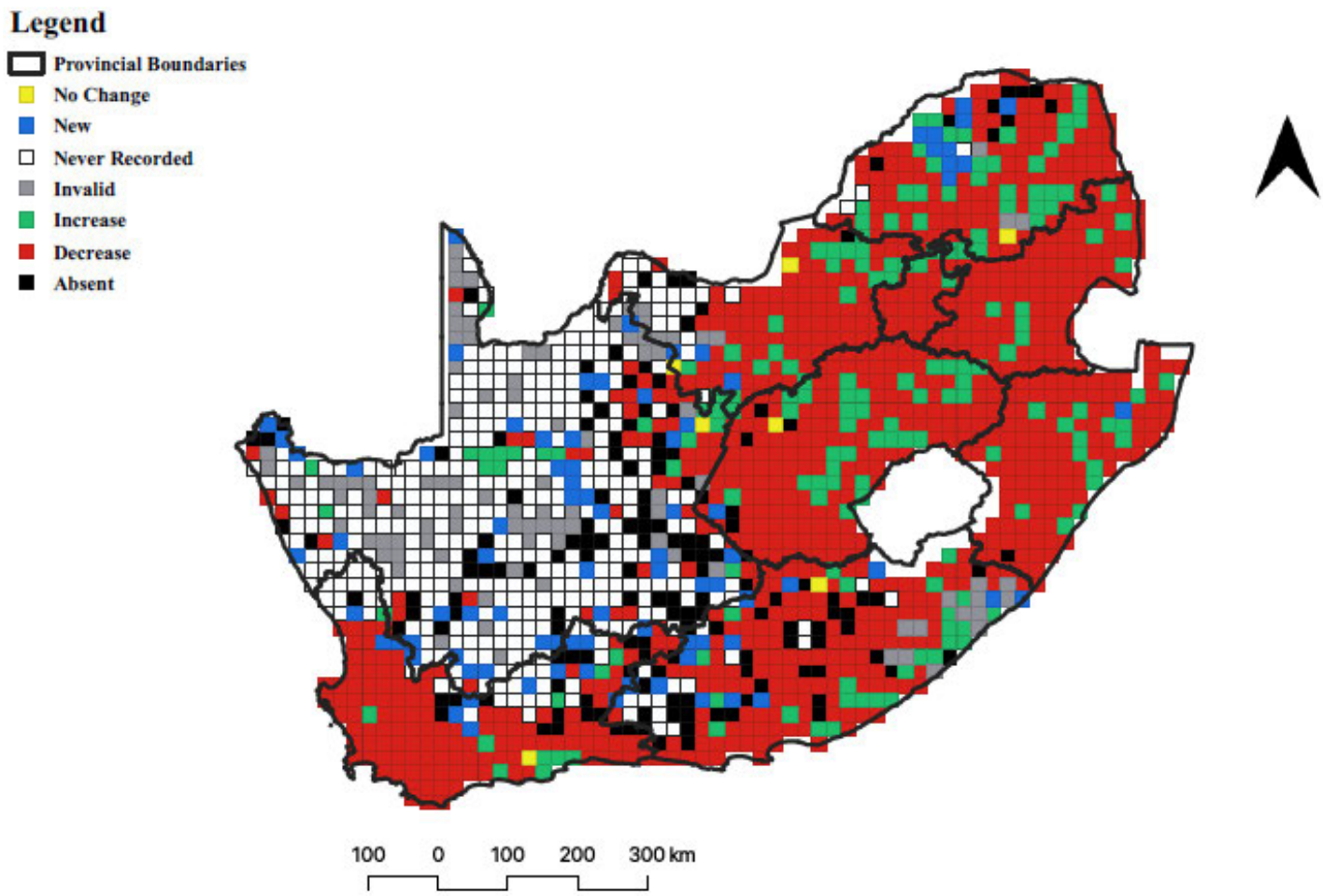

Figure 3.1: Western Cattle Egret reporting rates between Southern African Bird Atlas Projects ((SABAP1) and (SABAP2)) extracted from quarter degree grid cells (n = 1878). (Note: Cells with 'new records' in SABAP2 that were not present in SABAP1 are represented in blue; white cells show areas where the study species went unrecorded in both projects; green cells represent an 'increase' (C > 1); black cells represent areas where the study species was recorded in SABAP1 but not SABAP2; red cells show a decrease (C < 1) in the reporting rate during SABP2 compared with SABAP1; grey cells show areas with less than four (<4) checklists in either of the SABAP projects ; yellow cells show areas which have had no change in the reporting rate between both SABAP1 and SABAP2).

Table 3.2: Total number of quarter degree grid cells (QDGC) at the national and provincial level. (Note: The total number of cells was separated accordingly. Cells which showed an increase (C > 1 or new record), decrease (C < 1 or absent record), no change/stable (C = 1). Cells which were invalid (checklists < 4) for analysis, and those with no record of Western Cattle Egret sightings in both SABAP1 and SABAP2).

Area	**Number of QDGC**	**Increase**		**Stable**	**Decrease**		**Other**	
		C >1	New record	No change (C = 1)	C <1	Absent	No record	Invalid
National level								
South Africa	1878	188	87	7	974	161	355	106
Provincial level								
KwaZulu-Natal	165	18	1	0	143	2	0	1
Eastern Cape	278	33	14	1	157	41	16	16
Gauteng	23	2	0	0	21	0	0	0
Mpumalanga	124	14	0	0	109	0	1	0
Free State	200	35	1	1	156	7	0	0
Western Cape	231	12	14	1	146	22	35	1
Northern Cape	541	18	45	1	46	73	280	78
Limpopo	171	36	10	1	107	10	3	4
North West	145	20	2	2	89	6	20	6

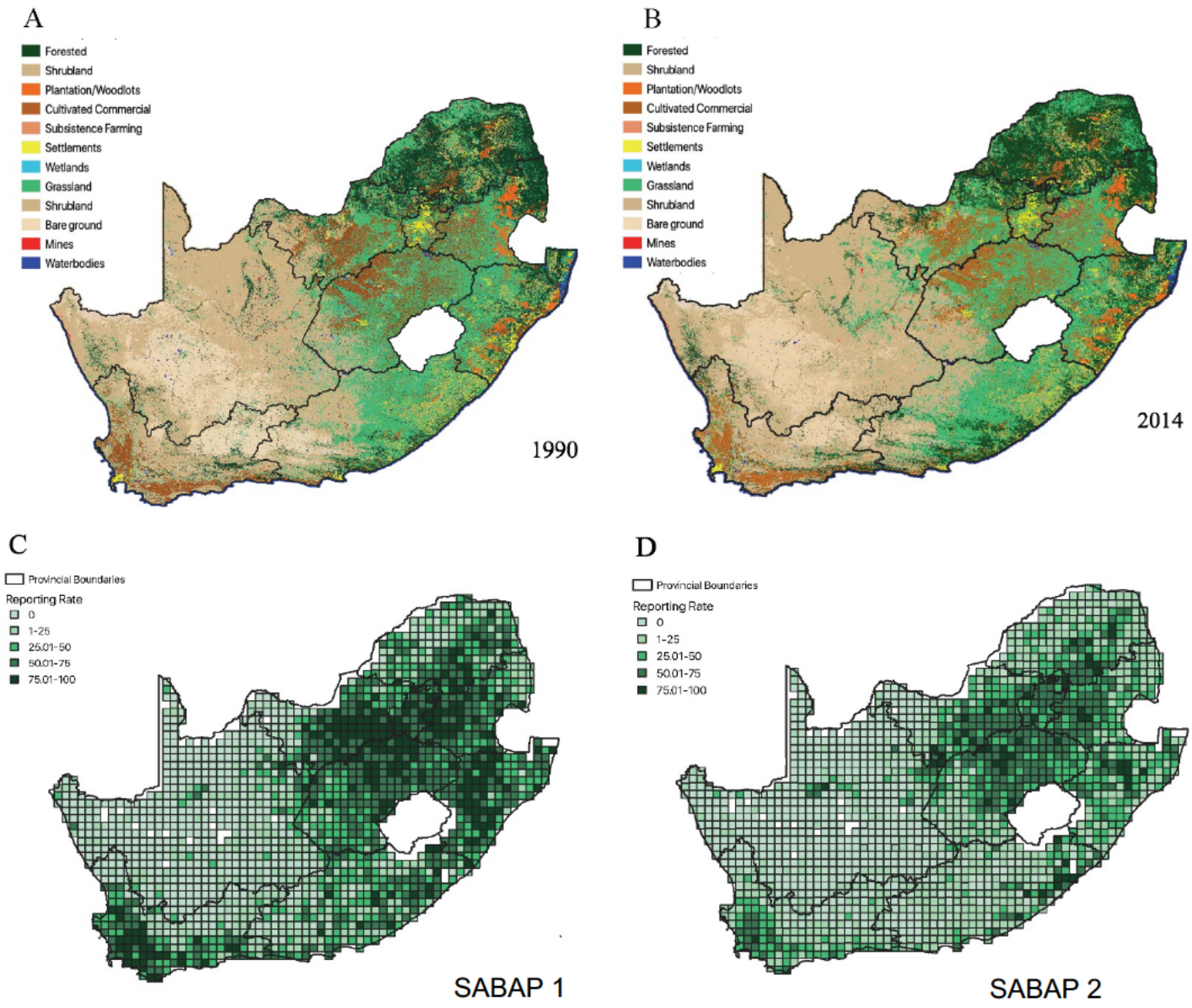

Figure 3.2: South African landcover from (A) 1990 and (B) 2014 and reporting rate percentages for Western Cattle Egrets across South Africa recorded between 1987–1993 (C) SABAP1 data, and data recorded between 2007–2023 (D) SABAP2. White spaces observed along the borders represent regions where the QDGC cell falls onto the neighbouring country. These cells are omitted from this study as we were only interested in South Africa.

Areas with decreased reporting rates in SABAP2 compared with SABAP1 (Fig 3.2 C & D) generally coincided with a decrease in grassland habitat seen in 2014 compared with 1990 (Fig. 3.2 A & B) as seen in the western regions of Eastern Cape and Free State. We also noted an increase in cultivation, forests, human settlements and woodlots in areas of decreased reporting rates (Fig. 3.2).

3.5 Discussion

The border length of a single QDGC is nearly equivalent to the 30 km home range of the study species (Maddock 1994; Hockey et al. 2005; Kopij 2017). It can be inferred that a single cell represents the home range of the Western Cattle Egret reported. Changes observed in Western Cattle Egret reporting rates between the two South African Bird Atlas Projects (SABAP1 and SABAP2) are indicative of the changes in species' presence and relative abundance across the nation. The greatest proportion of change observed was in decreased reporting rates in SABAP2 (than in SABAP1), possibly indicative of a loss or dispersion of entire colonies.

The Northern Cape continues to have a low Western Cattle Egret occurrence rate. The sightings that were recorded in the province in SABAP1 are of a higher frequency than in SABAP2, and there has been a decrease in reporting rates during the second project. Expansive parts of the Western Cape have had no Western Cattle Egrets reported over the duration of both SABAP projects (Fig. 3.2), highlighting that the matrix of arid shrubland and bare ground does not support Western Cattle Egret persistence. Western Cattle Egrets were absent from cells within the KwaZulu-Natal and Lesotho border along the Drakensberg Mountains (Fig. 3.1 and Fig. 3.2). The Queenstown and Graff-Reinet regions of the Eastern Cape, which border Lesotho, are also mountainous. Siegfried (1965) suggests that Western cattle egrets avoid high-altitude grasslands,

likely because of a lack of food availability. This could explain the lack of sightings in these regions. The recording of other species in these mountainous regions indicates that the lack of recordings is unlikely to be caused by the absence of active observers.

This pattern of decreased reporting rates was observed in all nine provinces, suggesting a change in relative abundance, inferring changes in distribution over the past 15 years, possibly longer. This is supported by the number of 'New' recordings in SABAP2, particularly in the Western Cape, Eastern Cape, Northern Cape and Limpopo. The Northern Cape experienced the lowest overall reporting rates but the highest number of new recordings (n = 45) of all provinces. The number of QDGCs which report an increase in sightings in Limpopo, Free State, Eastern Cape and North West could suggest favourable habitats (such as wetlands, grasslands and urban street trees) which promote Western Cattle Egret persistence.

Landcover changes, particularily grassland extent, display a pattern analogous to the reporting rates of Western Cattle Egrets in SABAP2 compared with SABAP1. A decrease in reporting rates between SABAP1 and SABAP2 in Mbombela correlate to the transformation of Sour Bushveld to forest and the transformation of taller reeds as a result of eutrophication in wetlands (McKenzie 2011). Observations were made of an increase in woodland bird species, which coincided with the increase of *Acacia ataxacantha*, alien invasive trees and the encroachment of *Lantana camara* (McKenzie 2011). Anthropogenic planting of trees in urban areas for aesthetic purposes and the southern extension of savannah biome into areas previously classified as grassland has led to increased woody vegetation across the Gauteng Province (Symes et al. 2017; McPherson et al. 2021), possibly providing habitat for roosting. Artificial dams have increased water availability in some provinces (Symes et al. 2017), causing an increase in wetland bird reporting rates (McKenzie 2011; Symes et al. 2017). Further studies are needed to explore the

longterm sustainability of wetland bird occupancy in arid habitats with artificial wetlands, especially across seasons.

Datasets of this magnitude would be difficult to obtain if not for the participation of citizen scientists (Hofmeyr et al. 2014; Harebottle 2019). The bird atlas data provided enough information to create visualisations and make inferences on the population changes of the study species whilst removing spatial and temporal barriers. Further studies are required to investigate the cause of the decline of Western Cattle Egret abundance in various areas of South Africa in addition to the impact of natural and or anthropogenic landscape changes along with anthropogenic climate change on nest site selection and habitat use. They are generally common residents in KwaZulu-Natal Province and exhibit high natal philopatry (Siegfried 1965; Kopij 2017; SABAP2 2023), yet this study showed a decrease of over 87% in reporting rates. Overlaying population trends with environmental trends may begin to highlight the challenges faced. However, while bioclimatic pressures exist, the role of urbanisation must also be considered.

3.6 Acknowledgements

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CHAPTER 4

Heronry site selection and population estimates of Western Cattle Egrets (*Bubulcus ibis*) in urban landscape mosaics in KwaZulu-Natal, South Africa

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4.1 Abstract

In Africa, the Western Cattle Egret *Bubulcus ibis* has had a notable increase in range distribution, particularly expanding throughout southern Africa and becoming a common breeder. However, with a growing human population, there is a high rate of habitat degradation, conversion of land for agriculture and urbanisation. We investigated heronry site selection and population estimates of Western Cattle Egrets within the uMgungundlovu (Pietermaritzburg) and eThekwini (Durban) Municipalities, KwaZulu-Natal, South Africa, from October 2018 to March 2020. These areas are both urban mosaic landscapes with some remaining natural green areas as well as managed green spaces with urban built. We conducted a population estimate of Western Cattle Egrets within these districts and identified characteristics which allow their urban roost persistence. An increase in population from under 500 individuals in 2018 to over 600 individuals in the post-breeding season in 2019 was observed, however no significant difference in population size between the breeding and the post-breeding seasons was found in either district. All Western Cattle Egret roosting and nesting colonies were within 10 km of a landfill, wetland, major road, river, and grassland. In addition, nesting sites were more likely to be near a wastewater treatment facility than roosts without nests. The nesting sites were in 27 trees on both commercial and residential properties. Differences observed in mean tree height were significant. *Vachellia xanthophloea* and *Jacaranda mimosifolia* were used on commercial properties. A significant difference was observed for the mean tree height. The tallest trees used for roosting were *Eucalyptus* spp. (20.23 m) and *Jacaranda mimosifolia* (19.52 m) found at Mpophomeni. The highly adaptive Western Cattle Egrets have become cosmopolitan, persisting through phenotypic plasticity in behaviour and undertaking various forms of migration to exploit available resources in the urban landscape mosaic. However, their persistence is affected by human-egret conflict.

Keywords: urban landscape mosaic, Western Cattle Egret, urban roost habitat use, population size estimates, nest site selection, urban wetland

4.2 Introduction

Natural spaces are steadily being transformed by rapid human expansion (McKinney 2006; Aronson et al. 2014; Downs et al. 2021). In the KwaZulu-Natal Province of South Africa, urban residents are expanding into neighbouring peri-urban and rural areas. In many parts of the province, this is exacerbated by traditional landowners under the Ingonyama Trust who seek development opportunities (Boon et al. 2016; Sutherland et al. 2016). This rapid densification has led to the degradation of the natural environment (McKinney 2006; Eigenbrod et al. 2011; Aronson et al. 2014; Sutherland et al. 2016; Maseko et al. 2020; Downs et al. 2021). Generally, such degradation leads to a loss of ecosystem services and species richness (McKinney 2006; 2008).

As natural resources become homogenised and natural habitats transformed, bird species continue to persist in urban habitats (Spelt et al. 2019; Shivambu et al. 2020; Wood and Esaian 2020). Due to their sensitivity, birds either become displaced (urban avoiders) as they avoid urban habitats in their entirety or adapt, clustering in habitats that allow the persistence of their survival (urban adapters) (Chace and Walsh 2004; Marzluff 2016; Murgui and Hedblom 2017; Symes et al. 2017; Maseko et al. 2020). Such adaptations are observed in mating behaviour, land-use and foraging (Marzluff 2016; Murgui and Hedblom 2017).

While natural selection is the obvious scientific explanation for wildlife's ability to adjust to urban environments, social learning is also likely, such as changes in fear response to humans (Marzluff 2016; Murgui and Hedblom 2017; del Barco-Trillo 2018), especially as humans provide supplementary feeding (Erz 1966; Evans et al. 2011; Thabethe and Downs 2018). For instance,

the Western Cattle Egret (*Bulbucus i. ibis*) can be observed foraging alongside waste pickers at landfills (Fig. 4.1a). Urban areas offer accessible food sources through landfills (Gilbert et al. 2016; Thabethe and Downs 2018), streetlights (Toloa et al. 2017) and wastewater treatment works (Fig. 4.1b) (Harebottle et al. 2008). Globally, landfill sites have become an important food resource for birds within/surrounding urban environments (Bochenski and Jerzak 2006; Ciach and Kruszyk 2010; Annorbah and Holbech 2012; Gilbert et al. 2016; Noreen and Sultan 2020; Arnold et al. 2021).

The highly adaptive Western Cattle Egret has become cosmopolitan, persisting in a variety of habitats, including human-transformed landscapes, through phenotypic plasticity and behavioural flexibility (Marzluff 2016; Downs et al. 2021) undertaking various forms of movement to exploit available resources (Kopij 2017). Genetic studies have been conducted (Congrains et al. 2016) to understand their range expansion and opportunistic use of suitable vacant habitats. Western Cattle Egrets have numerous breeding sites throughout South Africa outside of their previously known range (Kopij 2016). In KwaZulu-Natal Province, South Africa, breeding is thought to last for six months, beginning in August and ending in January. However, studies on the urban roosting of Ardeidae are lacking in southern Africa (Kopij 2017; Harebottle 2019). While range expansion continues, forming a new colony requires more than suitable vegetation and adequate food supply (Kazantzidis et al. 2013).

We located Western Cattle Egrets' roosting and nesting sites and documented their use in the urban landscape mosaics of two of KwaZulu-Natal's largest metropolitan areas, Pietermaritzburg (uMgungundlovu Municipality) and Durban (Ethekwini Municipality), KwaZulu-Natal, Province, South Africa. Roosts being where the birds congregate at night, while nesting sites are roosts which are used throughout the day for breeding and chick rearing. We used

counts conducted at roosts and nesting sites to determine population estimates. Our objectives were to (1) determine the population estimates of Western Cattle Egrets' during the breeding and post-breeding season, (2) identify key characteristics which aid in Western Cattle Egrets' persistence in an urban mosaic landscape (i.e., breeding near homes, breeding in heronries), and (3) measure the tree height of trees used for roosting and determine whether the roosting tree or nesting tree is indigenous or exotic. We predicted that Western Cattle Egret populations would be relatively high in the post-breeding season. We predicted that streams and urban wetlands would be key characteristics in Western Cattle Egret urban persistence and that there would be no preference for roosting trees as other studies have shown opportunistic behaviour. We also predicted that Western Cattle Egret roosts are independent of one another, each representing a separate colony and numbers remaining relatively stable during the non-breeding period.

Figure 4.1: Western Cattle Egrets supplementary feeding in human-modified habitats in KwaZulu-Natal, South Africa, where a.) shows foraging in a Pietermaritzburg landfill and b.) foraging in a Durban Wastewater Treatment facility.

4.3 Methods

4.3.1 Study area

Our study focused on the city of Pietermaritzburg (uMgungundlovu district, KwaZulu-Natal, South Africa) and its' surrounds, and Durban (eThekwini district, KwaZulu-Natal, South Africa) and its' surrounding communal lands and farmlands (Fig. 4.2). KwaZulu-Natal has the second largest human population of all nine South African provinces, with ~12.4 million people (Statistics South Africa, 2022). Durban, which lies in the eThekwini Municipality, is the third-largest city in the country and the largest city in KwaZulu-Natal. According to the eThekwini Biodiversity Report (2022), the human population is just over 4 million. Despite the rapid development and expansion of human settlements, the landscape is an urban mosaic with natural and managed green spaces. The Durban Metropolitan Open Space System (D'MOSS) was developed to connect these green spaces, and 7.2% of the 95,000 ha is under official protection, creating refugia for over 520 species of birds and 11 vegetation types (eThekwini Biodiversity Report 2022). The municipality lies along the Indian Ocean Coastal Belt (eThekwini Biodiversity Report 2022). It has an annual rainfall of ~1,000 mm (Maseko et al. 2020), with the winter month of June having the lowest precipitation levels (http://en.climate-data.org/africa/south-africa/kwazulu-natal/durban-511/).

The district of uMgungundlovu hosts Pietermaritzburg, the second-largest city and capital of KwaZulu-Natal. The district has a population of ~1,100,000 people at a density of 110/km^2 (Community Survey 2016); 38% of this population resides in the rural areas, according to the Ministry of Cooperative Governance and Traditional Affairs (COGTA 2023). The city is positioned within the Msunduzi River Valley, where there are natural and managed green spaces with natural vegetation in the form of parks, gardens, and conservancies (Josiah and Downs 2022). It has a subtropical climate with 966 mm annual precipitation, peaking during the summer month

of January along with average temperatures of 16.7°C (http://en.climate-data.org/africa/south-africa/kwazulu-natal/pietermaritzburg-634/)

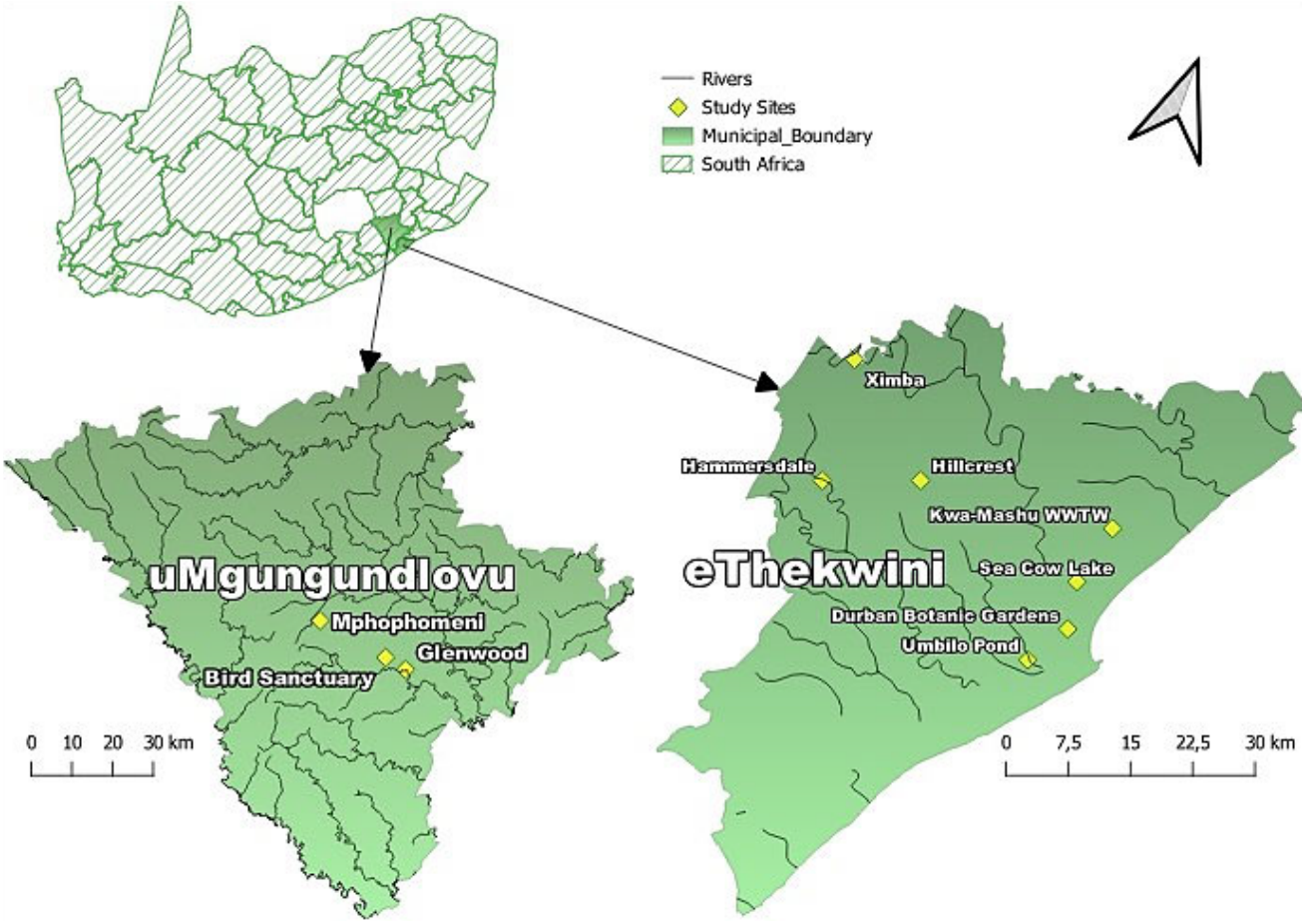

Figure 4.2: Western Cattle Egret roosting sites in the urban mosaic landscapes of uMgungundlovu and eThekwini municipalities, KwaZulu-Natal, South Africa, during the present study.

4.3.2 Study species

Western Cattle Egret males sometimes have darker breeding plumage than females (Ahmed 2011; Louw 2005). They are 46–56 cm in length with a wingspan of 88–96 cm (Fig. 4.3). The average adult weighs 360 g but is typically between 340–390 g, while males reach 512 g (Hancock and

Kushlan 1984; Scott 1987; Telfair 2006). They are medium-sized birds with heron-like characteristics. Though most herons have long elongated necks, the Western Cattle Egret's is short and thick. Their lore and iris are yellow. Sexual maturity is reached as early as 2 years of age (Hancock and Kushlan 1984; Kaufman 1996; Telfair 2006). During the breeding season, their legs turn from a greyish-yellow to bright red. This is also when their typically white plumage becomes rufous around the breast, back and crown, and their long, sharp, yellow bill becomes orange (Fig. 4.3a) (Hancock and Kushlan 1984; Kaufman 1996; Telfair 2006). Western Cattle Egret chicks have white down feathers, a bushy crown, dark olive-green legs and a downward curved yellow bill (Hancock and Kushlan 1984; Kaufman 1996; Telfair 2006). The olive-green legs and bill become black in fledglings (Fig. 4.3b) and then yellow in juveniles. Juveniles are nearly indistinguishable from adults except over breeding periods (Kaufman 1996; Telfair 2006). Western Cattle Egrets are a highly gregarious species (Blaker 1967) and exhibit high site fidelity. Monospecific colonies are prevalent. However, roosting in mixed colonies with other wetland species such as herons *Ardea cinera, Ardea melanocephala*, *Nycticorax nycticorax*, *Egretta garzetta*, *Pelecanus rufescens*, *Threskiornis aethiopicus*, *Ardea purpurea*, *Microcarbo africanus*, and *Anhinga rufa* is common (present study). Roosts are typically near lakes, rivers, marshes, coastal lagoons, bays, swamps, deep water or riparian ecosystems (Hancock and Kushlan 1984; Parnell et al. 1988).

4.3.3 Sampling techniques

We used social media, spoke with locals, and put an advertisement in Birdlife KwaZulu-Natal's newsletter to request sightings of Western Cattle Egret roosts and nest sites. Reports and feedback from the public allowed us to find the geographical locations of Western Cattle Egret roosts and

nest sites. If two or more Western Cattle Egrets were observed in a tree or bush late in the evening, it was considered a roost, and confirmation from locals was sought when possible. If two or more Western Cattle Egrets were observed in a tree or bush with a nest present, it was considered a nesting site, and confirmation from locals was sought when possible. Upon confirmation, roosts were monitored monthly from September 2018- September 2019. To account for seasonality monitoring began an hour before sunset, 16h00 in the winter months and 17h00 in summer. Two observers performed counts of all Western Cattle Egrets present. Roosts were then observed for ~2 h, counting flocks as they arrived (following Toloa et al. 2017). Observations were made using binoculars (Nikon Monarch 5 12 x 42 binoculars).

Figure 4.3: Western Cattle Egrets a.) breeding adults in a nesting site at kwaXimba in the present study, and b.) a juvenile admitted into FREEME Wildlife Clinic, Howick, KwaZulu-Natal. (Credits: J. Cele).

We recorded the geographical location coordinates of roosting sites using a Global Positioning System (GPS) (Garmin GPSMAP 64 Mapping Handheld GPS) and mapped these using the open-source Quantum Geographic Information System (QGIS) (QGIS.org, 2020). We identified the trees used for roosting or breeding. Where possible, we measured tree height using the application Globe Observer (Global Learning and Observations to Benefit the Environment (GLOBE) Program, *January 2020,* globe.gov) developed by NASA. In the event that access to the tree was restricted because of private property or water barriers, tree height was estimated using accessible trees as a reference. We also noted whether the tree species was a native or an exotic species to South Africa. The habitat type was determined using satellite imagery, and distance from a water source was measured.

4.3.3 Data analyses

We analysed the population estimate data using a t-test to compare population sizes across the breeding and post-breeding periods. Mean (± SD) of Western Cattle Egret counts were computed from monthly sightings. Since Western Cattle Egrets can forage up to 30 km from their roost (Maddock 1990; Hockey et al. 2005, Kopij 2017), consequently, using QGIS (QGIS.org, 2020), we created buffers of 0.5 km, 1 km, 10 km, 20 km and 30 km around roosting sites. We measured the distance from the tree occupied to select natural and anthropogenic features and amenities. Measurements at each roost site were presented as percentages to quantify which factors influence roost site selection. Additionally, tree height measurements were tabulated. Trees were grouped by species, and the mean (±SD), minimum and maximum measurements recorded (in meters: m), gave us a range of the tree sizes used for roosting. We used a One-way analysis of variance (ANOVA) to determine the difference in tree heights.

4.4 Results

4.4.1 Roost and nest sites

Four Western Cattle Egret roosts were found within 30 km of Pietermaritzburg's city centre. Two were nesting colonies only a few kilometres from one another. The seasonal Western Cattle Egret roost 'Glenwood' was found in a wetland bordering the Glenwood and Sobantu communities of Pietermaritzburg. This roost was 1 km from the Darvill Wastewater Treatment Works, where flocks were often seen foraging (Cele and Downs unpublished data). The trees occupied were adjacent to a seasonal Sacred Ibis *Threskiornis aethiopicus* roost. Approximately 10 km away was a roost used year-round, in the Pietermaritzburg City Centre, Townhill suburb, known as the Bird Sanctuary. This roost predates the city centre and was once a breeding colony (various pers. comm.). However, throughout this study, there was no evidence of breeding. The two roosts outside the city centre were all within 500 m of wetlands, grasslands, and peri-urban settlements.

At the site known as Bird Sanctuary in Pietermaritzburg, Western Cattle Egrets roosted in the reeds and overhanging vegetation of the pond (on arrival) throughout our study. Before sunset, Western Cattle Egrets left the pond to roost in the roadside fever trees *Vachellia xanthophloea* for the night. A nesting colony was found in Mpophomeni, about 27 km from the Bird Sanctuary roost, in the 2nd year of the study. The nesting colony of kwaXimba was also found ~27 km away. An additional roost is believed to be in the vicinity of Albert Falls Dam (various pers. comm.). No sightings of this roost were made during our study. Reports of a suspected roost in an area inaccessible by foot were received but not confirmed. A flock of over 100 Western Cattle Egrets were seen flying from Triple-A Beef feedlot towards the dam just as the sun was setting; however,

locals reported that there was no roost in their community, supporting claims that if present, the roost was in a remote area.

We located six Western Cattle Egret roosts in the north, outer west, and central spatial regions of eThekwini based on reports from the public. Two of which were nesting colonies found within 30 km of Durban's city centre, and four were seasonal roosts. A seventh roost was in a private golf estate in Hillcrest. Western Cattle Egrets were reportedly seen roosting in a tree overlooking one of the lakes in the estate. It is unknown whether this is also a nesting site. We observed low-flying Western Cattle Egrets enter the estate as the sun was setting, but we were not permitted access to the estate for evening counts. Although we were not permitted access to the golf estate, we managed to monitor the roosts from a public road in direct view of the lake despite this challenge. We found that this roosting site was used inconsistently, and no nests were observed in the trees from our view. There may be a roost within the estate at a location that we could not view from the public road, or individuals who roost at this site may form part of a neighbouring colony, so for this study, it was not counted as an official roost. All other eThekwini roosts were found within 30 km of this one. Satelitelite roosts such as this one could provide refuge from habitat loss, even if short-term.

Sums of monthly Western Cattle Egret counts between October 2018 and September 2019 in uMgungundlovu and eThekwini, KwaZulu-Natal, varied (Fig. 4.4). Roosts experienced an increase in population size in late December just after the breeding season (Fig. 4.4). In total, we found ten roosts, four of which were nesting colonies. These four nesting colonies were spread across 27 trees, with the colony at kwaXimba occupying ten trees in 2019. KwaXimba falls within eThekwini municipality but is near Pietermaritzburg's city centre. Given the size of this colony and the absence of the birds outside of the breeding season, this was included. Analyses were

performed on the breeding and post-breeding seasons from 2018-2019. The data were normally distributed (Shapiro-Wilk Test, breeding p = 0.171, post-breeding p = 0.270). There was no significant difference in the population size between the breeding and post-breeding season (t = -2.0684, df = 10, P = 0.06546) (Fig. 4.5).

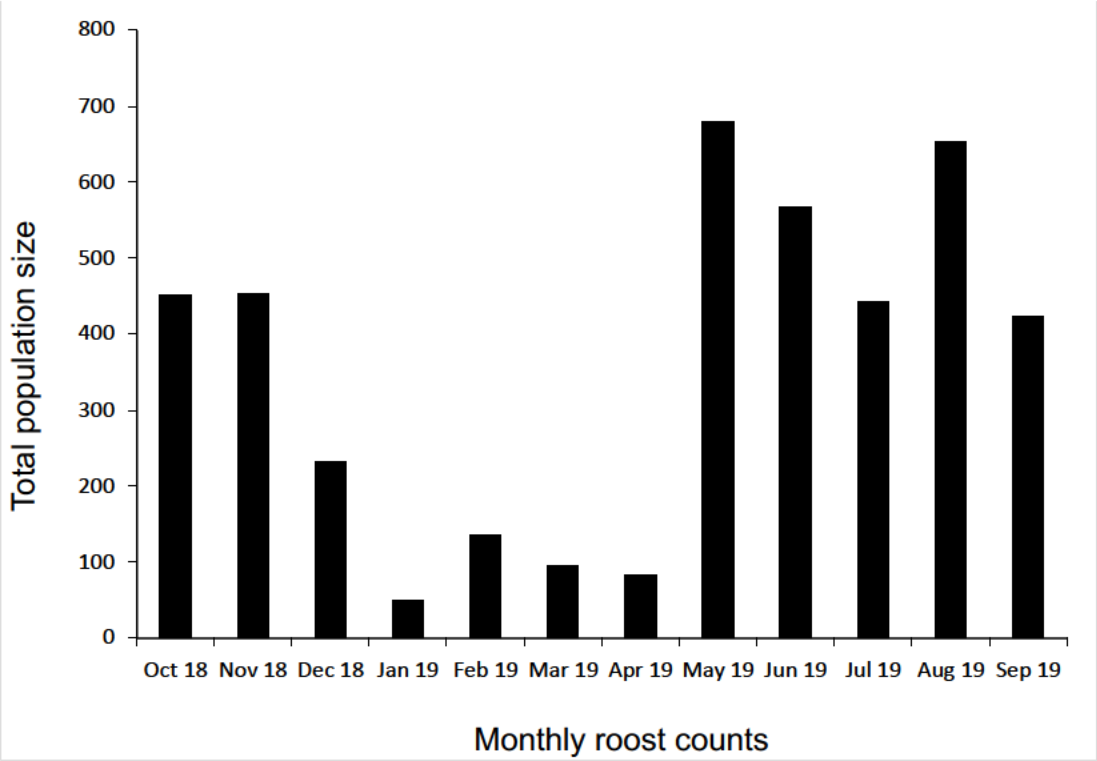

Figure 4.4: Sums of monthly Western Cattle Egret counts at roosts between October 2018 and September 2019 in uMgungundlovu and eThekwini, KwaZulu-Natal Province, South Africa.

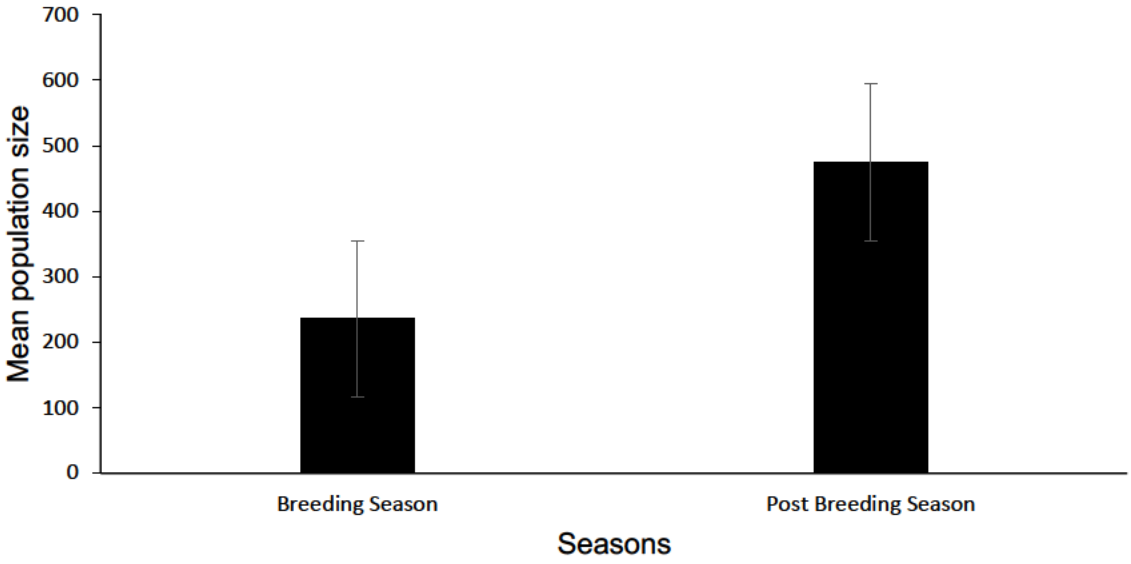

Figure 4.5: The means (± SD) estimated Western Cattle Egret populations in spring 2018 (breeding season) and autumn 2019 (post-breeding season) in uMgungundlovu and eThekwini combined.

4.4.2 Habitat selection

The habitat type "natural water" was found within 10 km of 12% of nest sites and 14% of roost sites, while "water dam" was within 10 km of 16% of nest sites and 10% of roost sites (Table 4.1, Fig. 4.6). The Bird Sanctuary roost, Pietermaritzburg, was on a tree-lined street adjacent to an artificial wetland. This roost offered minimal foraging opportunities within the 1 km buffer, but gaping at insects under the streetlights has been observed (Cele and Downs unpublished data).

The seasonal roosts had many species of Ardeidae and Perciformes present, yet Western Cattle Egrets generally congregated away from the other birds. Roosting colonies were often small or consolidated onto neighbouring trees. All (100%) Western Cattle Egret roosting and nesting trees were within 10 km of a landfill, wetland, major road, river, and grassland (Fig 4.6). In

addition, 100% of nesting trees were within 10 km of a wastewater treatment facility, while ~ 57% of roosting trees were within 10 km of a wastewater treatment facility. Approximately 70% roosting trees were within 10 km of forest and thornveld. District roads were found across all sites (Table 4.1).

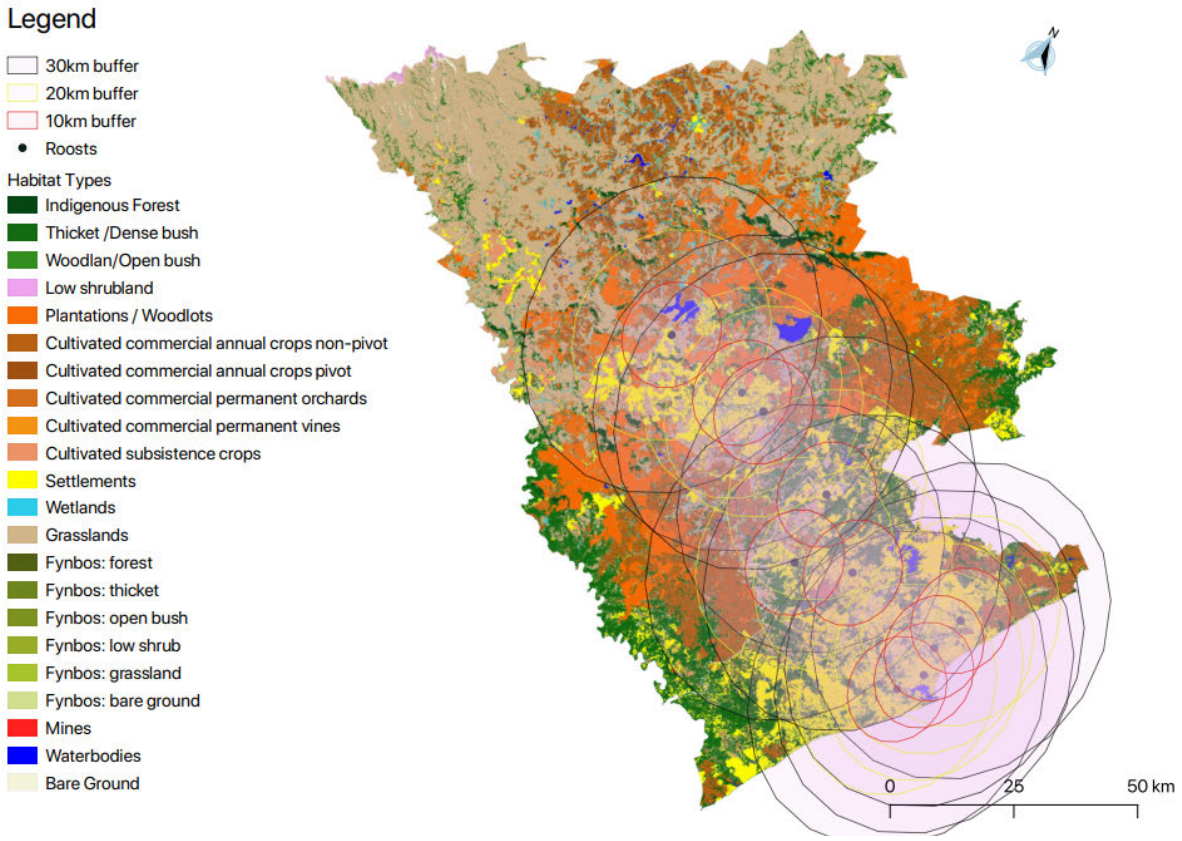

Figure 4.6: The habitat types associated with Western Cattle Egret roost sites within buffers of 10 km, 20 km, and 30 km radius

Table 4.1: Total and percentage of Western Cattle Egret roost only colonies (n = 4) and breeding colonies (n = 6) with various habitat types within a 10 km radius.

Habitat type	**Total Roosts**	**Roosts (%)**	**Total Breeding Colonies**	**Breeding Colonies (%)**
Plantation	0	0	1	16.7
Human settlement	4	100	6	100
Golfcourse	1	25	5	83.3
Landfill	0	0	2	33.3
Forest	3	75	2	33.3
Thornveld	1	25	5	83.3
Bushveld	2	50	2	33.3
Grassland	4	100	6	100
Veld	4	100		
KZN National Roads	2	50	6	100
KZN Main District Roads	4	100	6	100
Natural water bodies				
Wetlands	4	100	6	100
River	4	100	6	100
Artificial water bodies				
dams	3	75	3	50.0
Wastewater treatment works	4	100	4	66.7
Pond	1	25	3	50.0

Western Cattle Egret roosts in city centres were all near a pond. Generally, they were in trees found in areas of relatively low human traffic, near businesses or in the centre of a pond in a park. In peri-urban sites, trees used were found beside residential homes and community centres. The colony in kwaXimba used trees near residential homes and a funeral parlour. The colony in Mpophomeni used trees near residential homes and a community clinic. The Hammersdale colony showed a higher tolerance to human presence by not just roosting but nesting in trees along the main road in a high-traffic area. Like the colony in Pietermaritzburg's city centre, the trees occupied were taller than 5 m.

The Western Cattle Egrets in this study used both native and exotic trees (Table 4.2 and Table 4.3). The difference in mean tree height was significant (ANOVA, F = 4.059, df = 9, P = 0.004). The highest trees used for roosting were *Eucalyptus* spp. and *Jacaranda mimosifolia* found at Mpophomeni at 20.23 m and 19.52 m, respectively (Table 4.2). *Vachellia tortilis* at 3.2 m in kwaXimba and 3 m at Glenwood were the shortest trees selected for roosting (Table 4.2).

Table 4.2: Tree species, min, max, and mean (± SD) of Western Cattle Egret roosting trees across periurban sites within uMgungundlovu and eThekwini Metropolitan Municipality

GPS coordinates	**Location of roost**	**Tree species**	**Common name**	**Exotic/ Native tree species**	**Min. height (m)**	**Mean ± SD height (m)**	**Max. height (m)**
-29.5631655, 30.1863071	Mpophomeni	*Eucalyptus spp.*	Gum tree	Exotic	20.23	N/A	20.23
-29.5631655, 30.1863071	Mpophomeni	*Vachellia xanthophloea*	Fever tree	Native	11	11.3 ± .42	11.6
-29.5631655, 30.1863071	Mpophomeni	*Jacaranda mimosifolia*	Blue Jacaranda	Exotic	14.28	16.9 ± 3.7	19.52
-29.6626975, 30.6359262	kwaXimba	*Vachellia tortilis*	Umbrella thorn acacia	Native	2.46	2.8 ± .35	3.2
-29.6626975, 30.6359262	kwaXimba	*Melia azedarach*	White Cedar	Exotic	5	6.51 ±1.93	9.88
-29.5939587, 30.4332893	Glenwood	*Vachellia tortilis*	Umbrella thorn acacia	Native	3	3 ± 0	3

Threats faced by Western Cattle Egrets in urban mosaic landscapes were found (Fig. 4.7). Contrary to suggestions, most sites lacked alternatives to existing nesting and roosting trees. The removal of trees used for nesting during the breeding season led to displaced fledglings being

sprawled across the roof of the clinic and on neighbouring trees not commonly used for roosting. Adult Western Cattle Egret remains were observed at the base of roosting trees which had been cut down (Fig. 4.7).

Table 4.3: Tree species, min, max, and mean (± SD) of Western Cattle Egret roosting trees across urban sites within uMgungundlovu and eThekwini Metropolitan Municipality

GPS Location	Location of roost	Tree species	Common name	Exotic/ Native tree species	Min. height (m)	Mean ± SD height (m)	Max. height (m)
-29.7979650, 30.6546899	Hammersdale	*Jacaranda mimosifolia*	Blue Jacaranda	Exotic	6	6.2 ± .28	6.4
-29.8478386, 31.0074721	Durban Botanic Gardens	*Cinnamomum camphora*	Camphor tree	Exotic	5	5 ± 0	5
-29.7284662, 31.0123460	KwaMashu wastewater treatment works	*Trichilia dregeana*	Forest Natal-mahogany	Native	9.88	9.88 ±0	9.88
-29.7964081, 30.9959453	Sea Cow Lake	*Ficus burkei*	Common wild fig	Native	6	6 ± 0	6
-29,7581503, 30.7683274	Hillcrest	*Syderoxylon inerme*	Milkwood	Native	3.25	3.25 ± 0	3.25
-29.8952972, 30.9755927	Umbilo Pond	*Pinus elliottii*	Slash pine	Exotic	3.5	3.5 ± 0	3.5
-29.5855498, 30.3751769	Bird Sanctuary	*Vachellia xanthophloea*	Fever tree	Native	6.3	6.3 ± 0	6.3

Figure 4.7: Examples of threats faced by Western Cattle Egrets at study sites during the present study where a.) shows displaced fledglings sprawled across the roof of the clinic and on neighbouring trees not commonly used for roosting, b.) stumps of several nesting trees cut down during study period, c.) the stump of a roosting tree removed at the Bird Sanctuary, Pietermaritzburg, d.) Western Cattle Egret fatality caused by tree removals at the Bird Sanctuary, e.) a roosting tree removed from a residential home, and f) remains of a fledging in a nest with an aggressive sibling at KwaXimba.

4.5 Discussion

Our study documented roosting and nesting sites of Western Cattle Egrets in the urban landscape mosaics of two of KwaZulu-Natal's largest metropolitan areas. Roosts within city centres were all near a pond in relatively low-traffic areas. The Hammersdale roosting and nesting colony was an exception, as it was in a high-traffic area, in trees along the main road. Most roosts were used throughout the year, but others were used intermittently and were likely satellite roosts. Further research is needed to conclude whether there is connectivity between this satellite roost and either of the other sites.

We found that Western Cattle Egret roosts experienced an increase in population size just after the breeding season as the newly fledged chicks joined the adult population. Seasonal roosts were occupied in winter, just before the start of the breeding season, decreasing again by summer. As to be expected, sites used for nesting experienced a population increase in spring due to breeding pair additions, followed by a population decrease by autumn as chicks fledged.

In selecting between exotic or native tree species for roosting or nesting, Western Cattle Egrets were indiscriminate in these urban mosaic landscapes. Native tree species used to roost were generally of a lower height than the exotic trees used. Of the native species, *Vachellia tortilis* seemed to be the most commonly used in periurban communities. *Vachellia xanthophloea* was observed as a decorative street tree on commercial properties, as was *Jacaranda mimosifolia*. Several studies have examined the woody species selected by Western Cattle Egrets, particularly for nesting. A North American study showed they had a strong preference for nesting in *Rhus toxicodendron* (Burger 1978). In Algeria, they were reported nesting mainly in *Fraxinus angustifolia* (Gherbi-Salmi et al. 2021), while in India, they showed a preference towards building

nests in *Prosopis juliflora*, *Tamarindus*, *Acacia* spp., *Ficus* spp., *Casuarina* spp. and *Azadirachta* spp. (Reddy et al. 2023). In Pakistan, their nests were in both *Vachellia nilotica* and *Syzygium cuminii* (Abdullah et al. 2017), while they used various *Vachellia* spp. trees and shrubs in Uganda (Toloa et al. 2017). Lawson (1964) recorded Western Cattle Egrets breeding in the mangroves of Durban Bay. It appears that the Western Cattle Egret uses a wide range of tree and shrub species that are sturdy enough to hold their nests. Their existence in urban areas seems to be facilitated by the presence of street trees, both native and exotic (Measey et al. 2020; Sarlin et al. 2022).

Like many waterbirds, the nesting and roosting of Western Cattle Egrets harm the tree species they occupy (Arendt and Arendt 1988). These sizeable colonies often cause noise pollution, foul odours and the unpleasant presence of guano deposits (Dusi 1977; 1979; Mora and Miller 1998; Garcia et al. 2011). In turn, the soil and trees exhibit chemical and mechanical alterations (Arendt and Arendt 1988; Garcia et al. 2011). Consequently, the Western Cattle Egret is regarded as a nuisance species.

Western Cattle Egrets' roosting trees or branches of these trees were removed just before the end of our study period at various locations; including kwaXimba, Bird Sanctuary, Mpophomeni, and Hammersdale. These communities cited the birds as a nuisance (various pers. comm.). While this made monitoring difficult, it highlights the complexities of human-wildlife interactions in urban mosaic landscapes. When negative, the conflict have potential subsequent effects on the persistence of species.

Our study identified the destruction of roosting and nesting sites as the main threat to population growth and persistence in these urban mosaic landscapes. Siblicide, predation of chicks by raptors and collection of adults to sell to spiritual practitioners (used as an aide in returning lost items) were observed as minor threats (Cele and Downs unpublished data).

At residential sites, many chicks fall from their nest or fall victim to siblicide (Mock and Parker 1986). Dead chicks on roads, lawns, and in trees, as well as dead adult birds, are regarded as unsightly by the public. Egrets were persecuted for the feather trade during the late 1800s while chicks used for human consumption (Parnell et al. 1988). According to Parnell et al. (1988), efforts were made in North America to better manage water bird colonies as early as the 1800s (the goal was to increase the number of wading birds). Similarly, in southern France, a heronry was successfully established in the Camargue to address habitat destruction and restore the breeding populations (Hafner 1983). Today, in many parts of the world, efforts are made to discourage the re-establishment of nests at heronries (Fellows and Paton 1988; Harebottle et al. 2019). Tactics aimed at frightening the birds away have generally only produced short-term results. They often return or establish a new roost nearby (Dusi 1979; Fellows and Paton 1988; Telfair et al. 1995). Managing nuisance heronries has not fully addressed residents' concerns or resulted in humanely treating birds. Techniques have not been developed to wholly address this problem (Dusi 1979; Harebottle et al. 2019).

The formation of nature reserves often protects ecosystems and species. Protected areas are not excluded from habitat degradation caused by species-environment interactions as they are not protected from water bird usage; such has been reported in European, African and Asian countries as well as parts of the Americas (Garcia et al. 2011). This conservation practice, while valuable, does not consider interactions between species or between a species and the environment in which they inhabit. Snep et al. (2016) suggest that all stakeholders must be considered when developing sustainable green cities. Ethekwini Municipality attempts to accomplish this through its integrative Durban Metropolitan Open Space System (D'MOSS) program (Boon et al. 2016). The role of stakeholders was observed in the present study as urban dwellers both aided in (pruning roosting

trees before rot set in) and discouraged (completely chopping down trees during the breeding period) roosting, affecting Western Cattle Egret persistence in these urban mosaic landscapes. Legislation is in place to mitigate heronry loss at the provincial level, though it may not be well known by the general public (Harebottle et al. 2019). An advantageous approach would be to see artificial roosts erected where trees have been removed, as suggested by Harebottle et al. (2019); however, this is unlikely to resolve the aforementioned conflicts with private landowners. Perhaps if erected at a satellite roost or in natural spaces near problematic roosts, these artificial structures could attract Cattle Egrets to conflict-free sites.

With a decline in occurrence observed on a national scale (Chapter 3), monitoring populations on a localised scale assists with evaluating causes in Western Cattle Egret's population dynamics. As an avian species well adapted to both terrestrial and aquatic habitats, further research is needed to understand how Western Cattle Egrets are affected by natural and anthropogenic changes in their respective environments. This study highlights how roosting and nesting sites are important in the persistence of Western Cattle Egrets. Also, this study highlights how roosting and nesting sites are being lost, and how that might impact Western Cattle Egrets population growth. It is evident that there is no/little compliance with legislation that seeks to protect roosting and nesting sites, and this is mainly because of a lack of knowledge. Therefore, we recommend community awareness/ education programmes that would educate the public about the importance of these trees (i.e., roosting and nesting sites) to the persistence of Western Cattle Egrets. These programmes could also be key in making the public tolerate and appreciative of Western Cattle Egrets.

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CHAPTER 5

GENERAL DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

5.1 Background

The interdisciplinary approach of urban socio-ecological science is a necessary response to urbanisation (Magle et al. 2012; Symes et al. 2017). Terrestrial and aquatic spaces have been replaced with anthropogenic modifications and infrastructure (Allan 2012). Urban expansion into neighbouring low-density areas intensifies the effects of the ecological crisis (Crooks et al. 2004; Altwegg et al. 2014; Archibald et al. 2017; Symes et al. 2017; Batary et al. 2018). Management decisions must counter the effects of the transformed landscape. One method has been to create urban green spaces in the urban landscape mosaic to meet sustainable development goals and allow the urban mosaic natural and managed green spaces to sustain the diverse needs of fauna and flora (Altwegg et al. 2014; Boon et al. 2016; Archibald et al. 2017; Symes et al. 2017; Batary et al. 2018; Downs et al. 2021).

The rapid human population growth throughout Africa impacts its natural fauna and flora (Downs et al. 2021; Gumede et al. 2022; Josiah and Downs 2022). With landscape transformations occurring in the global south (Altwegg et al. 2014; Boon et al. 2016; Archibald et al. 2017; Batary et al. 2018; McPherson et al. 2021; Downs et al. 2021), Africa still remains the least published in the topic of urban ecology (Awoyemi et al. 2023). Having the highest forecasted population growth by 2050, and ill-managed highly-dense informal human settlements (Boon et al. 2016; Downs et al. 2021), it will be conducive for studies conducted in future to be geared towards informing urban design strategies (Awoyemi et al. 2023). South Africa, though still low, leads the continent in research output on urban ecology (Awoyemi et al. 2023). The human-wildlife interface has been

well documented in Durban as the Ethekwini Municipality responds to the need to conserve natural spaces within a rapidly growing city (Boon et al. 2016; Downs et al. 2021). The Durban Metropolitan Open Space System (D'MOSS) of Ethekwini Municipality incorporates scientific findings in their spatial planning. The D'MOSS links and protects natural wildlife and indigenous green spaces as well as managed green spaces such as golf courses, public parks, industrial parks and private gardens, to name a few (Adams 2005; Boon et al. 2016; Downs et al. 2021). These refuge spaces improve survival and reproductive fitness (McKinney 2006; McKinney 2008; Ausprey and Rodewald 2011; Brambilla et al. 2018; Maseko et al. 2019; Gumede et al. 2020). The urban mosaic landscape provides habitats for nesting, often with decreased predation risks (Altwegg et al. 2014) and elevated resource provisioning (Fuller et al. 2008; Altwegg et al. 2014; Crooks et al. 2004; Altwegg et al. 2014; Singh and Downs 2016a,b; Thabethe and Downs 2018).

The wetland-associated bird species within the family Ardeidae are common residents of Afrotropical KwaZulu-Natal (Chapter 4). Having undergone dramatic landscape transformations because of agriculture, the loss of wetlands and urbanisation makes it an ideal region to study (Boon et al. 2016; McPherson et al. 2021; Downs et al. 2021). In the face of transformations, Ardeidae returns to sites years after displacement (Wachira 2017). Their adaptability is observed in their selection of nest sites (Toloa et al. 2017; Wachira 2017). They use exotic trees (i.e., *Eucalyptus* spp.) for roosting and nesting (Kopij 2008; Wachira 2017). Artificial wetlands, with their managed water levels, offer refugia and provide additional habitat and nutrient load (Fidorra et al. 2016). They influence the abundance and richness of wetland-dependent birds, and the vegetation types inform roosting and nesting opportunities (Santoro et al. 2010; Murray et al. 2014). Establishing urban nesting colonies can potentially restore populations lost during urban built habitat conversion (Wachira 2017).

5.2 Research findings and synthesis

5.2.1 Global distribution and ecology of the Western Cattle Egret

There are three subspecies of cattle egrets (Miller and Ryder 1978; Arendt and Arendt 1988; Ahmed 2011; Congrains et al. 2016) exhibiting slight differences in breeding plumage (Ahmed 2011) (Chapter 2). Categorised as an invasive species by the International Union for Conservation of Nature's Invasive Species Specialist Group (ISSG) (Moralez-Silva and Del Lama 2014). Their intra and inter-continental migrations (Browder 1973) have led them to the Galapagos Islands (Phillips et al. 2012; Moralez-Silva and Del Lama, 2014) and Hawaii (Stone and Anderson 1988; Moralez-Silva and Del Lama 2014), where they are invasive (Chapter 2).

Widely dispersed throughout Africa (Arendt and Arendt 1988), Western Cattle Egrets can travel distances of over 3500 km from their natal site (Kopij, 2017). The South African population is thought to originate from central Africa, supported by recoveries in Amdafok, northern Central African Republic of birds ringed in Johannesburg (Kopij 2017) and Wolmaransstad (Underhill et al. 1999). Years of ringing Western Cattle Egrets have enabled birders to track their movements (Maddock and Geering 1994).

The aggressive, often territorial Western Cattle Egret (Blaker 1967; Dusi and Dusi 1968; Burger 1978, Dami et al. 2006) breeds in gregarious colonies, limiting risks of predation (Blaker 1967; Dusi and Dusi 1968). However, they are not immune to predation, often losing their young and even adults (Dusi and Dusi 1968). Natural predators include snakes, raptors and mammalian carnivores (Blaker 1967; Dusi and Dusi 1968). Coupled with human presence, which may deter predators, nesting in urban habitats could benefit overall fitness (Wachira 2017).

5.2.2 Comparative analysis of the first and second Southern African Bird Atlas Project (SABAP) as a tool to examine distributions of an urban exploiter across South Africa

To explore current distribution and abundance patterns on a national scale, we compared citizen science reporting rates of SABAP1 against SABAP2 (Chapter 3). Changes observed in Western Cattle Egret reporting between the 1987-1993 South African Bird Atlas Project (SABAP1) and the 2007-present (SABAP2) are indicative of the changes in species' abundance across the nation (Chapter 3). The Northern Cape experienced the lowest overall reporting rate but the highest number of new recordings of all provinces (Chapter 3). The number of quarter-degree grid cells (QDGCs) which reported an increase in sightings could suggest an increase in favourable habitats, promoting Western Cattle Egret persistence (Chapter 3). While QDGCs with decreased reporting rates in SABAP2 compared with SABAP1 (Chapter 3) possibly indicate a loss or dispersion of entire colonies. As to be expected, arid regions of the Western Cape had no Western Cattle Egret sightings during the periods of both SABAP projects. There was a decrease in reporting rates on a national scale, which coincided with South Africa's changing landscape (Chapter 3). These areas also exhibited increased anthropogenic pressures. Other studies comparing SABAP1 with SABAP2 reporting rates credited the observed changes to landscape transformation (McKenzie 2011; Symes et al. 2017), a pattern seen across South Africa (McKenzie 2011; Symes et al. 2017; McPherson et al. 2021).

5.2.3 Population estimates of Western Cattle Egrets (*Bubulcus ibis)* in urban landscape mosaics in KwaZulu-Natal, South Africa

The response of Western Cattle Egrets to urban expansion in the KwaZulu-Natal Province context is poorly documented. To fill the gap in urban ecological information for the Western Cattle Egret

(*Bulbicus ibis*) we evaluated population estimates of the Western Cattle Egret in the urban mosaic of KwaZulu-Natal, South Africa (Chapter 4). Investigations into the distribution and population estimates of Western Cattle Egrets were conducted on a localised scale by studying roosting and nesting sites in two of KwaZulu-Natal's largest metropolitan areas (Chapter 4).

A total of 10 roosts were found in the urban landscape mosaics (Chapter 4). Even in city centres with a high population density, roosting sites were located in low-traffic areas within proximity to ponds (Chapter 4). The Hammersdale colony, used for roosting and nesting, was in proximity to a stream along a tree-lined main road with high-vehicular traffic and few pedestrians (Chapter 4). In addition to year-round roosts, satellite roosts were identified and occupied just before the start of the breeding season. This study found that permanent roosts experience an increase in population size just after the breeding season (Chapter 4). The extent of this remains unknown because of a loss of roosting and nesting trees during the study. Human-egret conflict is an unabating threat to the species' population growth and persistence in these urban mosaic landscapes (Chapter 4).

Little preference was shown towards exotic or indigenous trees (Chapter 4). Indigenous trees used to roost were of a lower height than the exotic trees. The indigenous *Vachelia tortilis* is commonly found in peri-urban communities, providing nesting habitat for Western Cattle Egrets. The planting of street trees facilitates their existence in urban areas (Measey et al. 2020), for example, indigenous *Vachelia xanthophloea* and exotic *Jacaranda mimosifolia* (Chapter 4).

The nesting and roosting of Western Cattle Egrets are harmful to the tree species over time (Arendt and Arendt 1988), causing chemical and mechanical alterations of the soil and trees (Arendt and Arendt 1988; Garcia et al. 2011). Chicks fall from their nest or die because of siblicide (Mock and Parker 1986), which is unsightly for the public. One resident described Western Cattle

Egrets as “bad parents” when recounting the number of chicks found on the ground from a nesting tree on her property (pers. comm.). While homeowners exercised more patience with the nuisances experienced, problematic nests in commercial properties and areas serving the general public were removed due to health concerns. The close proximity of the birds to humans was cited as posing risks such as avian influenza, and short-term illnesses such as nausea from the odour of the guano deposit-filled rotting trees (pers. comm.). Exotic and indigenous trees were pruned or fully removed during the breeding season, resulting in Western Cattle Egret fatalities (Chapter 4). This exemplifies the complexities of human-wildlife conflicts in the urban mosaic landscape (Chapter 4).

As cities continue to be hosts of biodiversity, sustainable green cities must consider the needs of all stakeholders (Snep et al. 2016) while not neglecting the requirements of wildlife in urban systems (Boon et al. 2016). This can be done by encouraging private landowners to prune roosting trees once all birds have fledged at the end of the breeding season rather than chopping down trees during the breeding period, which allows recovery of the trees without discouraging Western Cattle Egret persistence.

5.3 Recommendations for future studies

The Western Cattle Egret has managed to expand its range distribution worldwide, but its abundance and distribution change in South Africa appear to be contracting in some areas. Despite South Africa’s loss of grasslands over the years, it also persists by adapting to urban environments. Through awareness and proper management, this ‘nuisance’ species may find a place in society. Further studies are required to investigate the cause of the decline of Western Cattle Egret abundance in some areas of South Africa. As common residents in KwaZulu-Natal Province

(Siegfried 1965; Kopij 2017; SABAP2), a decrease of over 87% in reporting rates is of concern. Overall, changes were observed nationally. By further investigating population trends with respect to environmental trends, the full scope of the challenges faced by this species can be discerned. In particular, coupling bioclimatic pressures and anthropogenic land cover transformations with their presence and distribution is required. Western Cattle Egrets are well adapted to terrestrial and aquatic habitats, so further research on the changes in both environments is needed to understand how they are impacted in the long term.

In urban areas, Western Cattle Egrets are regarded as a nuisance species (Parkes et al. 2012) for their noise at roosts and messy guano deposits (Cele and Downs, unpublished data), subjecting roosting trees to removal (Parkes et al. 2012) (Chapter 4). In contrast, Western Cattle Egrets are welcomed by farmers as biocontrol agents for feeding on pests that decimate commercial crops and grasses grazed by livestock (Toloa et al. 2017). A benefit overlooked in urban communities is that they feed on house fly maggots, *Musca domestica* and blue bottle fly *Calliphora* spp. (Seedikkoya et al. 2007; Seedikkoya and Azeez 2009), which pose a public health risk as carriers of cholera and typhoid in the metamorphosed stage (Seedikkoya et al. 2007). Studies on the environmental benefits of Western Cattle Egret roosting are lacking in South Africa, and they should be seen as a biocontrol mechanism, which might influence public opinion, promoting heronries.

The active efforts towards heronry restoration seen in France (Hafner 1983) and North America (Parnell et al. 1988) are needed to counter the management attempts to discourage the reestablishment of heronries (Fellows and Paton 1988; Cele and Downs unpublished data). These short-term tactics (they return once the conditions are suitable again) (Dusi 1979; Fellows and Paton 1988; Telfair et al. 1995) do not address the concerns of stakeholders. Creating heronries in

artificial wetlands, as modelled by the Durban Botanical Garden and Umbilo Park, keeps the advantages of urban roosting while decreasing disturbance to the public and private homeowners. Further research on this would be advantageous to spatial planning in the urban mosaic landscapes and human-wildlife interfaces.

5.4 References

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